MARINE POLLUTION AND HYDROCARBONS: THE GOAL OF MINIMIZING DAMAGE TO THE MARINE ENVIRONMENT

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There are three overall goals in protecting the marine environment. These goals include: (1) protecting common interests and rejecting special interests, (2) minimizing environmental damage (the "negative goal"), and (3) utilizing the positive motivations of optimum order.[1]

The present analysis will focus on the second major goal of minimizing damage to the marine environment. This "negative goal" includes the five subgoals of: (1) prevention, (2) deterrence, (3) restoration, (4) rehabilitation, and (5) reconstruction.[2]

Since marine pollution problems involving hydrocarbons are well-publicized, this analysis will also concentrate on hydrocarbons. The hydrocarbons include oil and gas, but they also include organic contaminants, inhibitors and poisons. Chlorinated hydrocarbons, which are oil by-products, constitute some of the most dangerous poisons infecting the marine environment. Another group of oil by-products, plastics, are also particularly damaging to the marine ecosystem. These hydrocarbons will be analyzed and the problem of their presence in the marine environment will be examined. These analyses should dispel frequent misconceptions about marine pollution and should provide perspective on the real dangers threatening the oceans.

I. MINIMIZING ENVIRONMENTAL DAMAGE AND PREVENTING MARINE POLLUTION: WHAT IS THE POLLUTION PROBLEM?

While the first overall goal in preserving the marine ecosystem is protecting common interests and rejecting special interests, a second overall objective is the "negative goal" of "minimizing damage to the environment."[3] The first major subgoal of minimizing environmental damage is the prevention of marine pollution, which involves long-term efforts to minimize the occasions for injury.[4] While these goals were formulated to apply to the environment in general, they apply *a fortiori* to the sensitive ecosystems of the oceans.

From a historical standpoint, the Report of the UN Confer-

1. McDougal & Schneider, *The Protection of the Environment and World Public Order: Some Recent Developments*, 45 MISS. L.J. 1085, 1089-91 (1974) [hereinafter cited as McDougal].

2. *Id.* at 1090.

3. *Id.*

4. *Id.*

ence on the Human Environment[5] (Stockholm Report), which was formulated during the Conference in 1972, has several provisions dealing with prevention of pollution in general. The introductory provisions of the Stockholm Report refer to the necessity to insure "the preservation and enhancement of the human environment."[6] Part I, Paragraph 2 proclaims that "[t]he protection and improvement of the human environment is a major issue which affects the well-being of peoples and economic development throughout the world . . . ."[7]

The principles enumerated in the Stockholm Report include many supportive statements encouraging long-term efforts to minimize environmental damage. While the Stockholm principles overlap somewhat with the previously mentioned subgoals,[8] they should nevertheless be mentioned at this juncture. Under Principle 6 the goal is to halt the discharge of harmful quantities of toxic substances into the environment,[9] and under Principles 12 and 13 the goals are "to preserve and improve the environment"[10] and "to protect and improve [the] environment."[11] Similarly, Principle 24 calls for cooperation among nations for the "protection and improvement of the environment,"[12] and Principle 18 states that science "must be applied to the identification, avoidance and control of environmental risks . . . ."[13] It should be noted that Principle 18 conflicts with the restrictive provisions governing scientific research which are found in the Convention on the Law of the Sea[14] (LOS Convention), negotiated at the Third UN Conference on the Law of the Sea (UNCLOS III).[15]

Almost surprisingly, the general environmental principles of the Stockholm Report include a specific statement involving prevention of marine pollution. Under Principle 7, "States shall take all possible steps *to prevent pollution of the seas* by substances that are liable to create hazards to human health, to harm living re-

5. U.N. Doc. A/CONF.48/14/Rev.1 (1972) [hereinafter cited as Stockholm Report].
6. *Id.* at 3.
7. *Id.* at 3, part I, para. 2.
8. McDougal, *supra* note 1, at 1090.
9. Stockholm Report, *supra* note 5, at 4, prin. 6.
10. *Id.* at 4, prin. 12.
11. *Id.* at 4, prin. 13.
12. *Id.* at 5, prin. 24.
13. *Id.* at 5, prin. 18.
14. *Done* Dec. 10, 1982, *reprinted in* 21 INT'L LEGAL MATERIALS 1261, U.N. Doc. A/CONF.62/122 (1982) [hereinafter cited as LOS Convention].
15. *See, e.g., id.* arts. 245-65.

sources and marine life, to damage amenities or to interfere with other legitimate uses of the sea."[16] Among those recommendations in the Stockholm Report relating specifically to marine pollution, the major evidence of a quasi-preventive subgoal is found in Recommendation 92, Paragraph b. This provision states that countries should "take early action to adopt effective national measures for the control of all significant sources of marine pollution, including land-based sources, and concert and co-ordinate their actions regionally and where appropriate on a wider international basis."[17] However, the Stockholm Report basically leaves marine pollution issues to the decisionmakers at the Intergovernmental Maritime Consultative Organization (IMCO)[18] and to those who negotiated UNCLOS III.[19] This early abrogation of responsibility by the Stockholm Report to IMCO and UNCLOS III lends tangential support to the proposition that IMCO is the only international organization which should be utilized under Article 211 of the LOS Convention, the provision governing vessel-source pollution.[20]

The major LOS Convention provisions relating to marine pollution, Articles 192 and 193, reaffirm the overall goal of minimizing damage to the marine environment by asserting that countries have the obligation and duty "to protect and preserve the marine environment."[21] Article 194 even states that the antipollution measures must be "designed to minimize" the major types of marine pollution.[22]

Interestingly, the provisions subsequent to Articles 192 and 193 have apparently evolved in accordance with the five McDougal subgoals. The first McDougal subgoal of prevention is enumerated in Article 194, which is entitled "Measures to *prevent*, reduce and control pollution of the marine environment."[23] While the Stockholm Report uses the words "prevent or prevention" only infrequently, the LOS Convention uses them often. The admonition "to *prevent*, reduce and control pollution of the marine environment" is

16. Stockholm Report, *supra* note 5, at 4, prin. 7 (emphasis added).

17. *Id.* at 23, recommendation 92, para. b.

18. In 1979, the Intergovernmental Maritime Consultative Organization (IMCO) changed its name to the International Maritime Organization (IMO). However, the organization is still commonly known as IMCO, and will be referred to as such in this article.

19. *Id.* at 23, recommendation 92, para. a.

20. LOS Convention, *supra* note 14, art. 211.

21. *Id.* arts. 192, 193.

22. *Id.* art. 194, para. 3.

23. *Id.* art. 194 (emphasis added).

commonly used.[24] The subgoal of preventing accidents and preventing discharges is reflected in other frequently used phrases.[25]

To appreciate the magnitude of the problem of preventing marine pollution, it is necessary to delineate the different types of marine pollution. The LOS Convention basically categorizes pollutants by their origins, including: (1) toxic substances entering the oceans from land-based sources, through the atmosphere or by dumping; (2) vessel-source pollution; (3) pollution caused by resource exploitation; and (4) pollution from general activities at sea.[26] However, since most antipollution agreements have historically covered only a specific type of pollution, it becomes necessary to examine specific kinds of pollution. Therefore, the subsequent analysis will concentrate on technical aspects, and it should provide perspective for determining what areas and particular pollutants comprise the essence of the marine pollution problem.

A. Hydrocarbons

1. *Oil.*

a. *Classification by Origin.* When analyzing marine pollution, hydrocarbons should be subdivided into oil and natural gas (particularly liquefied natural gas). The persistent oils consist of crude oil, diesel fuels and heating oil. These oils do not readily dilute in water as compared with the refined oil products such as kerosine and gasoline.[27]

It is well-known that "[o]ne of the most visible and highly publicized pollutants in the world's oceans is petroleum."[28] Oil enters the oceans via a number of media, and theoretically, all of the origins of marine pollution listed in the LOS Convention apply to oil.[29] Massive tanker spills and oil well blowouts have dominated the news headlines since the tanker *S.S. Torrey Canyon* ran

24. *Id.* art. 194, paras. 1 & 4 (emphasis added); *see id.* arts. 195 & 196.

25. LOS Convention, *supra* note 14, art. 194, paras. 3(b)-(d).

26. *Id.* art. 194, para. 3.

27. Sweeney, *Oil Pollution of the Oceans*, 37 FORDHAM L. REV. 155, 155 (1968). *See generally* Moore, *How Not to Protect Our Oceans*, NEWSDAY, July 10, 1978, at 42, cols. 1-3 [hereinafter cited as *Our Oceans*].

28. STAFF OF SENATE COMM. ON COM., 94TH CONG., 1ST SESS., EFFECTS OF MAN'S ACTIVITIES ON THE MARINE ENVIRONMENT 14 (Comm. Print 1975) [hereinafter cited as MARINE ENVIRONMENT]; *see* Cowell, *Oil Pollution of the Sea*, in MARINE POLLUTION 353, 353-94 (R. Johnston ed. 1976).

29. *See* LOS Convention, *supra* note 14, art. 194, para. 3.

aground in 1967,[30] but oil pollution from land-based sources is a major problem which has received little publicity. Approximately 5 million tons of oil from the different major pollution sources entered the sea during 1970, and it was predicted that the total for 1980 would be approximately 10 million tons.[31] Since the collection of statistics relating to oil pollution often appears to be a function of the most recent publicized tanker accident, statistics are often dated and myopic. However, a few studies in the 1970's established baseline parameters, and extrapolations from these earlier statistics can provide an overview of the oil pollution problem. Oil pollution should be divided into three major categories: (1) land-based oil pollution[32] (including oil pollution from development of the continental shelf),[33] (2) ocean dumping of oil,[34] and (3) vessel-source oil pollution.[35]

(1) *Land-Based Oil Pollution.* Some authorities identify pollution by waste oil as one of the major types of pollution from land-based sources.[36] Waste oil pollution is often utilized as a term which is generally synonymous with land-based oil pollution. However, land-based oil pollution should be used as the proper

30. *See* E. COWAN, OIL AND WATER: THE TORREY CANYON DISASTER (1968); C. GILL, F. BOOKER & T. SOPER, THE WRECK OF THE TORREY CANYON (1967); Crain, *Troublesome Aspects of the Sedco 135 Disaster: Has the Plight of the Transnational Pollution Victim Really Improved in the Wake of Torrey Canyon?* 2 HOUS. J. INT'L L. 387 (1980); Nanda, *The "Torrey Canyon" Disaster: Some Legal Aspects*, 44 DEN. L.J. 400 (1967); Note, *Liability for High Seas Oil Pollution Cleanup Costs: Domestic and International Provisions*, 3 HASTINGS INT'L & COMP. L. REV. 473 (1980) [hereinafter cited as *Pollution Cleanup Costs*]. *See generally*, Cowell, *supra* note 28, at 356; Kalsi, *Oil in Neptune's Kingdon: Problems and Responses to Contain Environmental Degradation of the Oceans by Oil Pollution*, 3 ENVTL. AFF. 79 (1974); Leonhard, *IXTOC I: A Test for the Emerging Concept of the Patrimonial Sea*, 17 SAN DIEGO L. REV. 617 (1980); Walter & Maltezou, *Resource Recovery and U.S. International Trade: The Case of Waste Oil*, 3 ENVTL. AFF. 433 (1974) [hereinafter cited Walter]; Note, *IXTOC I: International and Domestic Remedies for Transboundary Pollution Injury*, 49 FORDHAM L. REV. 404 (1980) [hereinafter cited as *IXTOC I*]; Note, *Domestic and International Liability for the Bay of Campeche Oil Spill*, 6 INT'L TRADE J. 55 (1981) [hereinafter cited as *Campeche Spill*]; *Britain's Great, Ghastly Ooze*, NEWSWEEK, Apr. 10, 1967, at 48.

31. *See* Kalsi, *supra* note 30, at 79-80. "Approximately six million tons of oil entered the ocean in 1975 from all sources, or approximately two of every 1,000 tons consumed." Pedrick, *Tankship Design Regulation and Its Economic Effect on Oil Consumers*, 9 J. MAR. L. & COM. 377, 377 (1978). *See also* Meese, *When Jurisdictional Interests Collide: International, Domestic, and State Efforts to Prevent Vessel Source Oil Pollution*, 12 OCEAN DEV. & INT'L L.J. 71, 104-05 n.14 (1982).

32. *See* LOS Convention, *supra* note 14, art. 194, para. 3a.

33. *Id.* art. 194, para. 3(c)-3(d).

34. *Id.* art. 194, para. 3(a).

35. *Id.* art. 194, para. 3(b).

36. *See* Kalsi, *supra* note 30, at 79-80. For detailed analyses of waste oil from refineries and other land-based sources, see Cowell, *supra* note 28, at 362-64.

overall term,[37] and waste oil should be used to refer to oil which has been processed, used and then discarded. Naturally, much if not most land-based oil pollution will consist of waste oil, but these definitional distinctions are necessary. As the properly descriptive overall term, land-based oil pollution should be subdivided into: (1) river runoff, (2) urban runoff, (3) industrial wastes, (4) municipal wastes, (5) coastal oil refineries, (6) offshore development wastes (that is, oil from development of continental shelf areas),[38] (7) accidental spills, and (8) air-borne pollution.[39] In this area, statistics revealing the amount of oil pollution are sketchy, but some approximations can be made from studies completed during the 1970's:

a. river runoff—1.6 million tons per annum;[40]
b. urban runoff—.1 to .5 million tons per annum[41](river and urban runoff together, 1.9 million tons per annum);[42]
c. industrial wastes—.3 to 1.98 million tons per annum,[43] (industrial and auto crankcase oil wastes together, 3.3. million tons per annum);[44]
d. municipal wastes—.3 to .45 million tons per annum;[45]
e. coastal oil refineries—.2-.8 million tons per annum;[46]
f. offshore development wastes—.008 to .2 million tons per annum;[47]
g. accidental spills—1.5 million tons per annum;[48] and

37. *See* LOS Convention, *supra* note 14, art. 194, para. 3(a).

38. *Id.* art. 208.

39. *See* NATIONAL ACADEMY OF SCIENCE, PETROLEUM IN THE MARINE ENVIRONMENT 6 (1975) [hereinafter cited as NAS PETROLEUM]; Meese, *supra* note 31, at 104-05 n.14.

40. NAS PETROLEUM, *supra* note 39, at 14; MARINE ENVIRONMENT, *supra* note 28, at 16.

41. MARINE ENVIRONMENT, *supra* note 28, at 16; *see* NAS PETROLEUM, *supra* note 39, at 14 (.3 million tons p.a.).

42. Meese, *supra* note 31, at 104-05 n.14.

43. *See* MARINE ENVIRONMENT, *supra* note 28, at 16 (.3 million tons p.a.); NAS PETROLEUM, *supra* note 39, at 14 (industrial and municipal wastes combined equal .45 million tons p.a.); D. ROSS, INTRODUCTION TO OCEANOGRAPHY 335 (2d ed. 1977) (.3 to 1.98 million tons p.a.) [hereinafter cited as ROSS 1977].

44. Meese, *supra* note 31, at 104-05 n.14.

45. *See* MARINE ENVIRONMENT, *supra* note 28, at 16 (.3 million tons p.a.); NAS PETROLEUM, *supra* note 39, at 14 (municipal and industrial wastes combined equal .45 million tons p.a.); ROSS 1977, *supra* note 43, at 335 (.3 to .45 millions tons p.a.).

46. *See* MARINE ENVIRONMENT, *supra* note 28, at 16 (.2 to .3 million tons p.a.); NAS PETROLEUM, *supra* note 39, at 14 (.02 million tons p.a.); Meese, *supra* note 31, at 104-05 n.14 (.3 to .8 million tons p.a.).

47. ROSS 1977, *supra* note 43, at 335; *see* MARINE ENVIRONMENT, *supra* note 28, at 16 (.08 to .15 million tons p.a.) NAS PETROLEUM, *supra* note 39, at 14 (.2 million tons p.a.).

48. Meese, *supra* note 31, at 104-05 n.14.

h. air-borne oil pollution—.4 to 9 million tons per annum.[49]

While there has been relatively little research in the area of waste oil, there is mounting evidence to the effect that

> [a] significant cause of environmental despoliation is the disposal of waste oil deriving from personal, industrial and transportation sources. Once lubricating oil has served its purpose, it becomes a serious pollutant if discarded into the environment. Waste oils are not readily biodegradable because of the inherent thermal and oxidation stability of the contained hydrocarbons, and the resistance of certain oxidation-inhibitors intended to minimize oxidation during use.[50]

The fact that most waste oil is not readily biodegradable poses serious problems because, while the ultimate consequences of oil uptake in the food chain are still basically unknown,[51] oil has generally been considered to be biodegradable.[52] Therefore, since waste oil is in fact nonbiodegradable, its effect on the marine environment is deceptively greater than what might be expected with an oil spill involving crude oil.

The magnitude of the waste oil problem is directly proportional to the increased use of oil as a source of energy, especially in transportion.[53] According to a House subcommittee hearing on waste oil recovery, it is estimated that:

> Each year, from the 2.9 billion gallons of new oil purchased in the United States about 1.5 billion gallons of waste oil are generated. About half comes from automotive operations (including buses and trucks), and the other half from industrial use (including, e.g., railroad and marine engines, and metalworking). In 1980 the Environmental Protection Agency (EPA) estimated that 50 percent of used and waste oil was burned as fuel, 14 percent was used for road oiling or similar purposes, 29 percent was disposed either directly to the environment or with garbage and trash, and only 7 percent (100 million gallons) was re-refined or reclaimed.[54]

By comparison, in 1976 it was estimated that "[s]ome 2500 mil-

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49. MARINE ENVIRONMENT, *supra* note 28, at 16; *see* NAS PETROLEUM, *supra* note 39, at 14 (at least .6 million tons p.a.); Meese, *supra* note 31, at 104-05 n.14 (.1 to .6 million tons p.a.).

50. Walter, *supra* note 30, at 436.

51. MARINE ENVIRONMENT, *supra* note 28, at 15.

52. *Id.*; *Contra*, Wood, *Requiring Polluters to Pay for Aquatic Natural Resources Destroyed by Oil Pollution*, 8 NAT. RESOURCES LAW. 545, 552 (1976).

53. Editorial Comment, SMITHSONIAN, Jan. 1980, at 22 [hereinafter cited as *Comment on Acid Rain*].

54. *Waste Oil Recovery: Hearing Before the Subcomm. on Energy, Environment, and*

lion gallons of automotive and industrial lubricating oils . . . [were] used each year in the U.S.A., of which about half . . . [was] drained."[55] Also in 1973, "[o]ne study of New York City sewer water found oil and grease concentrations from 9 to 53 ppm[56] in dry weather and up to 9,000 ppm in wet weather periods."[57] "Firm data of eventual loss to [the] sea from these sources are just not available, and there are many complicating factors that make assessment difficult if not virtually impossible."[58] It is often assumed that all waste oil will eventually drain into the seas, but there is some authority to the contrary.

> It is often assumed that waste oil dumped on land by, say, the individual motorist amongst others, will somehow reach the rivers and hence the sea. There is ample practical evidence, mostly arising from European work, to show that this is not so; an estimate is 450,000 tons p.a. or even less. Further work in this area is, however, really necessary.[59]

Although these statistics tend to be a bit dated, they generally confirm the conclusion that a "major source of petroleum contamination in the oceans is from sewage effluent and surface runoff."[60]

Another type of land-based oil pollution is air-borne pollution. Although it has been called other names, such as atmospheric fallout,[61] or atmospheric rainout, the most accurate term is air-borne pollution. This viewpoint is impliedly, if not expressly, affirmed by the terminology used in the LOS Convention.[62] Air-borne pollution is such an important type of pollution that it is often categorized separately. However, it is more appropriately included as a subcategory of land-based pollution since jurisdiction over air-borne pollution is generally with the country causing the problem, the "point-source country."[63] Furthermore, the *Trail Smelter Arbi-*

Safety Issues Affecting Small Business of the House Comm. on Small Business, 97th Cong., 2d Sess. 92 (1982).

55. Cowell, *supra* note 28, at 363.

56. "Ppm" is the abbreviation for "parts per million."

57. MARINE ENVIRONMENT, *supra* note 28, at 15. Each year U.S. gas stations are estimated to dump 350 million gallons of waste oil into sewers which then flows untreated into the oceans. Kalsi, *supra* note 30, at 81.

58. Cowell, *supra* note 28, at 364.

59. *Id.*

60. MARINE ENVIRONMENT, *supra* note 28, at 15.

61. *See* Kalsi, *supra* note 30, at 80 (referring to "atmospheric fallout"). For a classic report on acid rain, see NATIONAL ACADEMY SCIENCE, ACID RAIN (1983).

62. *See* LOS Convention, *supra* note 14, arts. 194, 212, 222.

63. *See id.* art. 212, para. 1.

tration[64] demonstrated the ability of one country to proceed against another country for air-borne pollution.

While most air-borne pollution is generated on land and is therefore under the jurisdiction of the point-source country, air-borne pollution may also be generated by aircraft and ocean vessels. Air pollution by aircraft is and should continue to be regulated by the host State as modified by an appropriate international regulatory organization,[65] such as the International Civil Aviation Organization (ICAO).[66] The LOS Convention does not regulate aircraft in any way, but instead specifically safeguards the international right of overflight of all ocean areas,[67] including narrow straits[68] such as Gibraltar.

Article 212 of the LOS Convention states:

> *Pollution from or through the atmosphere*
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> 1. States shall adopt laws and regulations to prevent, reduce and control pollution of the marine environment from or through the atmosphere, applicable to the air space under their sovereignty and *to vessels flying their flag or vessels or aircraft of their registry*, taking into account internationally agreed rules, standards and recommended practices and procedures and the safety of air navigation.
>
> 2. States shall take other measures as may be necessary to prevent, reduce and control such pollution.
>
> 3. States, acting especially through competent international organizations or diplomatic conference, shall endeavor to establish global and regional rules, standards and recommended practices and procedures to prevent, reduce and control such pollution.[69]

The enforcement provisions in Article 222 of the LOS Convention authorize host State and flag State regulation of vessels and aircraft engaged in air-borne pollution by providing that:

> States shall enforce, within the air space under their sovereignty or with regard to vessels flying their flag or vessels or aircraft of their registry, their laws and regulations adopted in accordance with article 212, paragraph 1, and with other provisions of this Convention and shall adopt laws and regulations

64. (United States v. Canada), 3 R. INT'L ARB. AWARDS 1905 (1941); *see* Convention for the Settlement of Difficulties Arising from Operation of Smelter at Trail, B.C., Apr. 15, 1935, 49 Stat. 3245 (1935), T.S. No. 893 (effective Aug. 7, 1935).

65. LOS Convention, *supra* note 14, art. 212, para. 1.

66. *See* Convention on International Civil Aviation, Dec. 7, 1944, 61 Stat. 1180, T.I.A.S. No. 1591, 3 Bevans 944, 15 U.N.T.S. 295.

67. *See* LOS Convention, *supra* note 14, art. 87, para. 1(b).

68. *Id.* art. 39, para. 3.

69. *Id.* art. 212 (emphasis added).

> and take other measures necessary to implement applicable international rules and standards established through competent international organizations or diplomatic conference to prevent, reduce and control pollution of the marine environment from or through the atmosphere, in conformity with all relevant international rules and standards concerning the safety of air navigation.[70]

Accordingly, air-borne pollution is basically a subcategory of land-based pollution, even when the point source is not based on land but is caused by an aircraft or a vessel. Therefore, air-borne pollution generated by ocean vessels at sea should generally be treated as a type of land-based pollution because most air-borne pollution is generated by land-based operations and because the LOS Convention treats air-borne pollution as based on land.[71] Like air-borne pollution by aircraft, air-borne pollution by vessels would generally be under the jurisdiction of the flag State,[72] but theoretically this type of air-borne pollution could also be treated as pure vessel-source pollution. This would be feasible if a nexus could be established between the pollution and the vessel; for example, if a vessel were burning large amounts of trash while at sea.

In any event, "[o]ne of the largest and most difficult to estimate losses to the sea annually is from vaporization of petroleum products during their use or transport and subsequent precipitation at sea."[73] "Much research yet needs to be done in determining the precise magnitude and effect of the hydrocarbon transfer from land sources into the oceans owing to evaporation, but various estimates have asserted that as much as 10 to 90% of the oil in the seas is attributable to this source."[74] Current estimates of petroleum hydrocarbons entering the oceans are few, but a conservative estimate is that between 0.4 and 9.0 million tons enter the oceans each year.[75]

A basic cause of that species of air-borne pollution known as acid rain is the "headlong combustion of fossil fuels around the globe."[76] It has even been predicted that due to the energy crisis the United States will eventually "turn the Rockies into gasoline

70. *Id.* art. 222.
71. *Id.* arts. 194, 212, 222.
72. *See id.*
73. MARINE ENVIRONMENT, *supra* note 28, at 15.
74. Kalsi, *supra* note 30, at 81. For a discussion of crude oil evaporation, see Reijnhart & Rose, *Evaporation of Crude Oil at Sea*, 16 WATER RESEARCH 1319 (1982).
75. MARINE ENVIRONMENT, *supra* note 28, at 16.
76. *Comment on Acid Rain*, *supra* note 53, at 22-23; *see* NATIONAL ACADEMY SCIENCE,

and live it up another decade or so before we bubble off in a sea of acid fizz and leave it to the cockroaches to clean up."[77] A related aspect of air-borne pollution is tetraethyl lead utilized in gasoline. "[I]t is thought that more lead enters the ocean from the atmosphere by the burning of tetraethyl lead, which is used in gasoline as an antiknock agent, than is carried in by rivers."[78]

(2) *Ocean Dumping of Oil.* Ocean dumping is a term which is often confused with vessel-source pollution. The terms should be recognized as relating to two completely different processes. Ocean dumping consists basically of transporting wastes onto the ocean with the specific intent of depositing those wastes in the ocean. Article 1, Paragraph 5, of the LOS Convention defines ocean dumping as "(i) any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea; (ii) any deliberate disposal of vessels, aircraft, platforms or other man-made structures at sea."[79] Dumping does not include discharges "derived from the *normal operations* of vessels, aircraft, platforms or other man-made structures at sea and their equipment,"[80] other than discharges from specific ocean disposal installations operated as disposal sites.[81] Thus, vessel-source pollution consists basically of pollution discharged by the *normal operations* of the vessel or by maritime accidents.

Once the definitional ambiguities are clarified, it becomes apparent that there is no traditional ocean dumping of oil per se by the United States—except for isolated instances. One such instance occurred on November 30, 1970, when the United States Navy dumped 600,000 gallons of waste oil and sludge into the Atlantic Ocean, fifty-five miles off the Florida coast.[82] The result was an oil slick extending for one thousand square miles.[83] Incidents such as this make it apparent that even isolated instances of ocean dumping can have particularly damaging effects.

International ocean dumping of oil, however, has averaged ap-

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ACID RAIN (1983); *The Growing Furor Over Acid Rain*, U.S. NEWS & WORLD REP., Nov. 19, 1979, at 66.

77. *Comment on Acid Rain, supra* note 53, at 22.

78. D. ROSS, INTRODUCTION TO OCEANOGRAPHY 455 (3d ed. 1982) [hereinafter cited as Ross 1982].

79. LOS Convention, *supra* note 14, art. 1, para. 1.(5)(a).

80. *Id.* art. 1, para. 1.(5)(b) (empahsis added).

81. *Id.*

82. Kalsi, *supra* note 30, at 100 n.13. *See generally* LOS Convention, *supra* note 14, art. 194, para. 3.

83. Kalsi, *supra* note 30, at 100 n.13.

proximately .5 million tons per annum.[84] In light of these figures, the ocean dumping of oil should be banned completely because oil: (1) is a nonrenewable resource, (2) can generally be recycled, and (3) constitutes an increasing threat to the marine environment. The Convention for the Prevention of Pollution of the Sea by Oil (1954 Oil Convention)[85] is the basic international document regulating ocean dumping of oil. Articles 210 and 216 of the LOS Convention regulate ocean dumping in general.[86] While the 1954 Oil Convention and the LOS Convention are helpful international instruments, a total ban on the ocean dumping of oil is needed.

(3) *Vessel-Source Oil Pollution.* By definition, vessel-source oil pollution basically results from the normal operations of vessels on the seas and is often termed "intentional operational discharge."[87] Maritime accidents resulting in the discharge of oil should also be categorized as vessel-source pollution.[88] Even so, the majority of vessel-source pollution is caused by intentional operational discharge.

Intentional operational discharge occurs when oil supertankers intentionally fill their tanks with seawater and then flush them into the sea. Once tankers discharge their oil, they need to add water to their tanks for ballast; otherwise, they ride too high in the water when they put to sea.[89] After sailing to a new port, this water and oil residue is intentionally discharged before the tankers receive a new cargo. This deliberate pumping of oil into the sea by tankers is the major cause of vessel-source oil pollution.[90] Normal leakage from the ship's engines also contributes to vessel-source oil pollution, as does the illegal practice of flushing the ship's tanks with seawater to clean them while at sea. It can be argued that the ocean dumping of oil is really a type of intentional operational discharge and that therefore, the dumping of oil is more properly categorized

84. Meese, *supra* note 31, at 104-05 n.14.

85. May 12, 1954, 3 U.S.T. 2989, T.I.A.S. No. 4900, 327 U.N.T.S. 3 (entered into force Dec. 8, 1961, subject to an understanding, reservations and a recommendation); *as amended* Apr. 11, 1962, 2 U.S.T. 1523, T.I.A.S. No. 6109, 600 U.N.T.S. 332 (entered into force May 18 and June 28, 1967); *as amended* Oct. 21, 1969, 1 U.S.T. 1205, T.I.A.S. No. 8505 (entered into force Jan. 20, 1978, properly referred to as the 1954 Oil Convention and not as the London Convention).

86. LOS Convention, *supra* note 14, arts. 210, 216.

87. *See id.* art. 1, para. 1.(5)(a)-(b).

88. *Id.* art. 221.

89. *See* Kalsi, *supra* note 30, at 80.

90. *See* Payne, *Flags of Convenience and Oil Pollution: A Threat to National Security?*, 3 HOUS. J. INT'L L. 67, 81 (1980).

as vessel-source pollution and should be considered as such under the LOS Convention.[91] However, the definitional distinctions made in Article 1, Paragraph 5(b),[92] render this a specious argument.

Except for air-borne pollution, vessel-source pollution is the major route by which oil enters the oceans. Approximately fifty percent of the oil consumed worldwide is transported by sea in the world tank-ship fleet. This fleet numbers some six thousand vessels.[93] Approximately "0.1 percent of all oil transported by ships ends up in the ocean."[94] Estimates from the 1970's place the annual amount of vessel-source oil entering the oceans at approximately 2.133[95] to 2.45[96] million tons. These figures include both accidental spills from vessels and intentional operational discharge. Accidental spills account for approximately ten to fifteen percent of these totals.[97] Vessel-source pollution has often been considered to be synonymous with pollution from marine transportation, but marine transportation includes some land-based sources. Vessel-source pollution includes pollution from: (1) load-on-top (LOT) tankers, (2) non-LOT tankers, (3) nontanker vessels, and (4) all vessel accidents, both tankers and nontankers.[98] The tanker operations can be further subdivided into tank washing and deballasting, while the nontanker operations can be further subdivided into bilge pumping and deballasting.[99] Since accidental vessel-source oil pollution can fluctuate dramatically from year to year, both the tanker and the nontanker accidents should not be delimited in these subdivisions, but should be maintained as separate categories of vessel-source pollution. If this distinction is not made, the statistics can be

91. *See* LOS Convention, *supra* note 14, arts. 211, 216.

92. *Id.* art. 1, para. 1.(5)(b). *See supra* notes 79-81 and accompanying text.

93. Pedrick, *supra* note 31, at 377. A 1975 report estimates that 1.3 billion tons of oil are transported by sea each year. MARINE ENVIRONMENT, *supra* note 28, at 15.

94. ROSS 1977, *supra* note 43, at 334.

95. NAS PETROLEUM, *supra* note 39, at 6. *See also* Cowell, *supra* note 28, at 354-56. A 1977 U.S. Coast Guard estimate of oil pollution in U.S. waters was approximately 56,666 tons. *Comprehensive Oil Pollution and Compensation Act: Hearing on H.R. 85 Before the Subcomm. on Water Resources of the House Comm. on Public Works and Transportation*, 96th Cong., 1st Sess. 451 (1979) [hereinafter cited as *Oil Pollution Hearing*].

96. Meese, *supra* note 31, at 104-05 n.14.

97. MARINE ENVIRONMENT, *supra* note 28, at 16.

98. *See id.* at 16; Meese, *supra* note 31, at 104-05 n.14. If the LOT process were not used, intentional operational discharge would approach 4 million tons per year. Cowell, *supra* note 28, at 359.

99. *See* Meese, *supra* note 31, at 104-05 n.14.

confusing and even misleading.[100]

Marine transportation pollution includes all of the vessel-source pollution categories plus: (1) dry docking, (2) terminal operations, (3) bilges bunkering, and (4) nontanker accidents.[101] There are some definitional problems involved with these last four categories, and they should probably be categorized as land-based pollution since most pollution in these four areas will originate either on land or in the territorial seas. In this area, a case-by-case analysis should be used to determine whether a given type of pollution is vessel-source or land-based. In essence, the term marine transportation serves no useful purpose and should be eliminated.

Accidental oil spills are basically a type of vessel-source pollution, and as such they should be governed by IMCO to the extent that private and regional agreements fail.[102] Prompted by the *Torrey Canyon* accident, the International Legal Conference on Marine Pollution was held in Brussels in November of 1969 and resulted in two new conventions.[103] The public law convention which emerged was the Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualities.[104] This convention authorized a country to intervene and protect its coastline if an oil spill could reasonably be expected to cause major damage.[105] The private law convention was the Convention on Civil Liability for Oil Pollution Damage.[106] This Convention was later complemented by the Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage.[107]

In addition to these conventions, there are two major private

100. *Cf.* Meese, *supra* note 31, at 104-05 n.14.

101. *See* MARINE ENVIRONMENT, *supra* note 28, at 16. For an in-depth analysis of oil pollution from terminal operations, see Cowell, *supra* note 28, at 356-60.

102. *See* LOS Convention, *supra* note 14, art. 211 (which is governed by IMCO as the "international organization"). For an article delimiting accidental oil spills as "traumatic vessel-source pollution," see Anderson, *National and International Efforts to Prevent Traumatic Vessel Source Oil Pollution*, 30 U. MIAMI L. REV. 985 (1976).

103. *See* Gold, *Pollution of the Sea and International Law: A Canadian Perspective*, 3 J. MAR. L. & COM. 13, 23-24 [hereinafter cited as Gold]; Note, *Federal Common Law and Ocean Pollution*, 8 ENVTL L. 1, 7 (1977).

104. *Done* Nov. 29, 1969, 26 U.S.T. 765, T.I.A.S. No. 8068 (entered into force May 6, 1975).

105. *See* Bilder, *The Canadian Arctic Water Pollution Prevention Act: New Stresses on the Law of the Sea*, 69 MICH. L. REV. 1, 16-18 (1970); *Pollution Cleanup Costs, supra* note 30, at 477-79.

106. *Done* Nov. 29, 1969, *reprinted in* 9 INT'L LEGAL MATERIALS 45 (1970); *see* Crain, *supra* note 30, at 390-93; *Pollution Cleanup Costs, supra* note 30, at 479-94.

107. *Done* Dec. 18, 1971, *reprinted in* 11 INT'L LEGAL MATERIALS 284 (1972); *see* Crain, *supra* note 30, at 394-97.

agreements between the major oil companies and the owners of the tankers. The 1969 Tanker Owners Voluntary Agreement Concerning Liability for Oil Pollution (TOVALOP)[108] compensates governments for cleanup costs if a tanker negligently causes an oil spill.[109] Among other compensatory provisions, environmental damage on land or within territorial seas is redressed under the Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution (CRISTAL).[110] The applicable provision is Article IV.[111]

The greatest problem with oil spills is that they misdirect environmental efforts from the major marine pollution problems to the less important areas.[112] While accidental oil spills are dramatic and well-publicized, they promote a myopic approach to the overall problem of oil pollution—and to marine pollution problems in general. Accidental oil spills by tankers account for less than ten percent of all vessel-source pollution.[113] Even so, accidental oil spills are still a problem. Throughout the 1970's there were approximately 8,000 to 13,000 spills per year[114] in the United States, which totaled between 30,000 and 64,000 tons of oil products per year.[115] Estimates vary widely. "[F]or example, in the first half of 1973 the Coast Guard reported 800 oil spills in the mid-Atlantic region alone, ranging from one gallon to 450,000 gallons, and expected there to be 12,000 oil spills nationwide in 1973."[116] In 1977, there were 12,844 incidents, resulting in approximately 64,000 tons of spilled oil.[117] The United States Coast Guard classifies a spill of over 10,000 gallons in coastal waters or over 1,000 gallons in inland waters as a major spill. "Public awareness of the scope of ocean pollution was further heightened when Thor Heyerdal was quoted in the *New York Times* as saying that there is "a continuous stretch of at least 1400 miles of open Atlantic polluted by floating lumps of solidified asphalt-like oil."[118] Heyerdal was probably viewing the

108. Jan. 7, 1969, *reprinted in* 8 INT'L LEGAL MATERIALS 497 (1969).

109. *Id.* art. IV(A)-(B); *see* Gold, *supra* note 106, at 30-36.

110. Jan. 14, 1971, *reprinted in* 10 INT'L LEGAL MATERIALS 137 (1971).

111. *Id.* art. IV.

112. *Our Oceans*, *supra* note 27, at 42, col. 1.

113. MARINE ENVIRONMENT, *supra* note 28, at 16.

114. *See Oil Pollution Hearing*, *supra* note 95, at 96, 164.

115. *See id.* In 1975 there were 10,141 reported spills in the United States. These spills totaled 54,000 tons of lost oil. Gundlach, *Oil Tanker Disasters*, ENVIRONMENT, Dec. 1977, at 16.

116. MARINE ENVIRONMENT, *supra* note 28, at 15.

117. *Oil Pollution Hearing*, *supra* note 95, at 164.

118. MARINE ENVIRONMENT, *supra* note 28, at 15.

results of intentional operational discharge as distinguished from the results of accidental oil spills.

The increased incidence of accidental oil spills may be due in part to the increasing number of tankers transporting oil under flags of certain countries whose laws allow ships owned by foreign companies to fly their flag.[119] Shipping companies try to minimize costs and maximize profits by registering their vessels with a country that offers the greatest advantages while minimizing expenses.[120] The desired advantages generally include: (1) easy registration of vessels, (2) lower taxes, (3) reduced wages and other operating expenses, and (4) relative freedom from control by the country of registry.[121] As a result, many ships which are registered in these convenience countries have never even docked at the ports of these nations.[122] The majority of these convenience countries are classified as developing or underdeveloped nations, or as Third World countries.[123] Therefore, the country of registry often lacks the power or desire to assert meaningful control over its oil tankers.[124] In Liberia, for example, ship registration fees constitute approximately eight percent of the Liberian gross national product.[125] Accordingly, convenience countries are more likely to register substandard ships or to allow the use of minimally trained crews.[126] Uniform IMCO rules governing oil tankers may be necessary to insure a safe shipping industry,[127] since ninety-four percent of United States oil imports are transported primarily by these convenience tankers.[128]

On an international scale, there are approximately six thousand oil tankers, and each year about six percent of these tankers are involved in collisions or groundings. Unfortunately, many of these tankers are also involved in the illegal practice of cleaning their tanks while at sea by flushing them with seawater. Unbeknownst to most of these supertanker operators, it is now possible to "fingerprint" each ship and its cargo via a gas chromatograph

119. Payne, *supra* note 90, at 68.
120. *Id.* at 69.
121. *Id.*
122. *Id.*
123. *Id.* at 72.
124. *Id.*
125. *Id.*
126. *See id.* at 98.
127. *Id.* at 98-99.
128. *Id.* at 68.

(called a GC).[129]

> With hundreds of compounds in its makeup, any oil has individual characteristics. Like the fingerprints of humans—no two of which are the same—each oil from each source, whether it be underground, the pipes of a refinery, the storage tanks of a fuel depot or the hold of a supertanker, has its own set of fingerprints. A GC and its operator can get the prints of even a pinprick of oil.[130]

The GC can analyze oil samples which have been gathered from "oily mud, oily lobsters, oily clams, oily seaweed, oil scraped from the bottom of a yacht or a lobster trap, oily feathers, oily periwinkles and oil from the boot bottoms of the researchers . . . ."[131] The GC can identify not only the type of crude oil, but also the country of origin, and the exact tanker, even if the tanker is one of several ships carrying oil from the same region.[132] Utilizing this technique, marine environmentalists can now establish a definite nexus between a given oil discharge or environmental damage and a specific ship. The compilation of GC evidence against tankers suspected of illegal flushing should begin immediately; there is a good chance of catching some of the unwary who have been bathing in the luxury of illegally polluting the ocean commons.

(4) *Offshore Development as Land-Based Pollution vis-à-vis Vessel-Source Pollution.* Offshore development of oil resources is the final category to which the origins of oil pollution can be traced.[133] While oil pollution from offshore development is generally land-based, other LOS provisions involving vessel-source pollution and even ocean dumping would conceivably be relevant to offshore development pollution under certain circumstances. For example, offshore development may involve deepwater ports which of legal necessity should be situated in internal or territorial waters. While deepwater ports would constitute offshore installations and would be governed by Articles 194 and 208 of the LOS Convention,[134] the vessels utilizing these ports would be subject to the ves-

129. Cole, *Scientists Gauge Extent of Recovery After an Oil Spill*, SMITHSONIAN, Oct. 1979, at 69, 72 [hereinafter cited as Cole]. For an examination of how the oil cargo of a vessel can also be treated by "tagging" the oil with a combination of metal alloy particles, see Land, *"Fingerprinting" Offending Tankers*, SEA FRONTIERS, Mar.-Apr. 1982, at 102.

130. Cole, *supra* note 129, at 72.

131. *Id.*

132. *Id.*

133. *See* LOS Convention, *supra* note 14, art. 194, paras. 3(c)-(d).

134. *Id.* art. 194, paras. 3(c)-(d), 208.

sel-source provisions of the LOS Convention.[135] Thus, at a deepwater port an oil spill resulting from the off-loading of a tanker would be governed as pollution by an offshore installation, a subcategory of land-based pollution. If on the other hand the vessel slipped its moorings and began polluting the surrounding waters, vessel-source considerations would arise. These considerations would be further complicated if the deepwater port was located at the outer edge of a three-mile territorial sea, such as in the United States.

Similarly, ocean installations utilized for waste disposal would be governed by Articles 194 and 208 of the LOS Convention,[136] which would include installations in the economic zone and on the continental shelf.[137] Since the coastal State has primary jurisdiction, this utilization of offshore resources for waste disposal would be governed as a type of land-based pollution. However, such a platform or installation located near the outer edge of an economic zone might be engaged in despoiling the high seas, and questions would arise as to whether the platform or installation was really engaged in ocean dumping. Moreover, it could even be asserted that the platform or installation was engaged in vessel-source pollution if its definitional status as a platform or installation was challenged. By comparison, there have been a multitude of United States cases under the Jones Act[138] which have had to distinguish between a vessel and some other type of barge or installation.[139] Such determinations would have an impact on pollution issues and offshore development. Regardless of these types of imaginary horribles, offshore development needs to carefully balance economic concerns with the protection of the marine environment.

"Pollution from offshore drilling is estimated to amount to less than 4 percent of the amount entering the sea by ship operations."[140] Again estimates vary, but during the 1970's oil pollution from exploitation of offshore resources was estimated to be approximately 0.2[141] to 1.6[142] million tons per annum. Considering the

135. LOS Convention, *supra* note 14, arts. 194, para. 3(b), 211, 217-18, 220-21.

136. *See id.* arts. 194, paras. 3(c)-(d), 208.

137. LOS Convention, *supra* note 14, art. 208, para. 1.

138. 46 U.S.C. § 541 *et seq.* (1976).

139. For a discussion of U.S. cases involving the definition of "vessel," see Morris & Kindt, *The Law of the Sea: Domestic and International Considerations Arising from the Classification of Floating Nuclear Power Plants and Their Breakwaters as Artificial Islands*, 19 VA. J. INT'L L. 299, 301-03 (1979) [hereinafter cited as Morris].

140. MARINE ENVIRONMENT, *supra* note 28, at 15.

141. NAS PETROLEUM, *supra* note 39, at 14.

magnitude of the 1979 Pemex oil well blowout in Campeche Bay,[143] these estimates may need revision, but upon balancing the equities of the energy crisis vis-à-vis marine protection, offshore development should continue. In 1981 the United States continental shelf produced 377.5 million barrels of crude oil and 4.99 million cubic feet of natural gas.[144] As of 1983, the United States had eight thousand producing oil wells on the continental shelf, and since 1953 this area had "yielded more than 5.7 billion barrels of oil and more than 53 trillion cubic feet of gas."[145] Nevertheless, when the magnitude and environmental ramifications of illegal flushing and intentional operational discharge (without using load-on-top recovery techniques)[146] are balanced against the economic conveniences afforded tankers, the economic arguments are completely inadequate.

In the offshore areas, some petroleum seeps into the oceans naturally. A site where this process is occurring is known as a natu-

142. Meese, *supra* note 31, at 104-05 n.14. Estimates of oil pollution from offshore production vary:

> Available statistics show that for U.S.A. Federal leases, the drilling of some 8000 wells led to 24 blowouts of which six involved oil and only one gave rise to significant pollution. Again, regarding the 11,000 or so wells in the Gulf of Mexico, 27 blow-outs occurred, leading to oil pollution in only two cases.
>
> . . . .
>
> Estimates of the total quantity of oil entering the oceans each year as a result of offshore activity have been made by several authors, but there is an evident lack of accurate figures. For example, U.S. Government reports estimate the amount of oil lost to sea at Santa Barbara as between 3000 and 10,000 tons. Corino (1971) estimates 100,000 tons p.a. discharge during normal operations, and Holdsworth (1971) suggests 30,000 tons p.a. arising from accidents; Porricelli (1971) gives a 100,000 ton total for all off-shore operations. Alcan Shipping Services Ltd. (1971) have suggested a total loss of 150,000 tons, two-thirds of which is attributed to normal operations. Similar figures have been quoted by other authorities.

Cowell, *supra* note 28, at 361; *see* Shutler, *Pollution of the Sea by Oil*, 7 HOUS. L. REV. 415, 417 (1970).

143. *See* Leonhard, *supra* note 30, at 617; *Campeche Spill*, *supra* note 30, at 55; *IXTOC I*, *supra* note 30, at 404; Beck & Henkoff, *Texas: The Oil Spill is Coming*, NEWSWEEK, Aug. 13, 1979, at 24 [hereinafter cited as Beck]; *The Great Gulf Oil Spill Wrangle*, NEWSWEEK Sept. 10, 1979, at 26 [hereinafter cited as *Oil Spill Wrangle*]; *When a Giant Oil Slick Hits U.S. Shores—*, U.S. NEWS & WORLD REP., Aug. 20, 1979, at 50 [hereinafter cited as *Oil Slick*].

144. ENERGY INFORMATION ADMINISTRATION, U.S. DEP'T ENERGY, PUB. NO. DOE/EIA-0340(81)/1, 1 PETROLEUM SUPPLY ANNUAL 1981 44 (1982) (377.5 million barrels of crude oil); ENERGY INFORMATION ADMINISTRATION, U.S. DEP'T ENERGY, PUB. NO. DOE/EIA-0131(81), NATURAL GAS ANNUAL 1981 12 (1982). *See also* NAS PETROLEUM, *supra* note 39, at 6 (oil pollution a minor part of the overall pollution problem).

145. SENATE COMMISSION ON COMMERCE, SCIENCE, AND TRANSPORTATION., OCEAN AND COASTAL DEVELOPMENT IMPACT ASSISTANCE BLOCK GRANT ACT, S. REP. NO. 112, 98th Cong., 1st Sess. 2 (1983).

146. For an analysis of load-on-top recovery techniques, see W. WATERS, T. HEAVER & T. VERRIER, OIL POLLUTION FROM TANKER OPERATIONS—CAUSES, COSTS, CONTROLS 75-89 (1980).

ral seep. The average amount of oil pollution caused by natural seeps is approximately 0.5 million tons per annum,[147] but "[n]atural seeps may represent a significant amount of the total amount of petroleum entering the marine environment . . . ."[148] "It has been estimated that 50 to 100 times as much oil has been lost to the environment through natural seeps as now exists in reservoirs."[149] Some of the earliest records of natural seeps date from approximately 50 years after the discovery of America.

> Fernandez de Oviedo referred to petroleum seepages in the Gulf of Venezuela, while Lopez de Gomera (1552) refers to petroleum seepages on Cabagua Island (Venezuela) and to corresponding stains in the neighbouring sea off Puerto de la Cruz. In 1579, Rodriguez de Arguelles reported oil seepages near to Nueva Zamora (Maracaibo) and four other places in the same province.[150]

A natural seep has been discovered off the coast of Alaska,[151] and "[t]wo natural seeps have long been known off southern California and seven are charted in the Gulf of Mexico."[152] Given the ever-increasing price of oil and the increasing difficulty in finding new sites, it would seem logical to drill offshore wells in the proximity of natural seeps to alleviate pressure on the seeps and capture as much oil as possible before it is lost and becomes pollution. For example, natural seepage in the Santa Barbara area "may be as high as 50 to 75 barrels per day (or about 2,100 to 3,150 gallons per day); this natural rate could, in as little time as 222 days, equal the amount spilled from the well [in the 1969 oil well blowout]."[153]

Unfortunately, the question of risk in developing offshore oil is largely an emotional one. It should be remembered that according

147. NAS PETROLEUM, *supra* note 39, at 14.

148. MARINE ENVIRONMENT, *supra* note 28, at 15. An interesting contrast to the natural seeps are the artificial seeps produced by sunken ships.

> A small source of oil pollution in the oceans is oil leaking from ships and tankers sunk during World War II and sunken marine casualties with oil tanks intact. But, there are 428 ships including 100 tankers sunk off the eastern coast of the United States with a staggering five million barrels of oil in their tanks. As their hulls corrode, these ships will become a serious potential source of pollution.

Kalsi, *supra* note 30, at 80-81. Sunken tankers may contain 5 million barrels of oil. Shutler, *supra* note 142, at 417.

149. MARINE ENVIRONMENT, *supra* note 28, at 15.

150. Cowell, *supra* note 28, at 353.

151. Kvenvolden, Weliky, Nelson & Des Marais, *Submarine Seep of Carbon Dioxide in Norton Sound, Alaska*, 205 SCI. 1264, 1264 (1979).

152. MARINE ENVIRONMENT, *supra* note 28, at 15.

153. ROSS 1977, *supra* note 43, at 337; *see* Baldwin, *The Santa Barbara Oil Spill*, 42 COLO. L. REV. 33 (1970); TIME, Feb. 14, 1968, at 23.

to 1975 estimates the amount of oil entering the oceans "from offshore drilling (80,000 tons per year) is 7.5 times less than from natural seeps (600,000 tons per year) and 26 times less than that from transportation (2,133,000 tons per year)."[154]

> Most public concern, however, usually centers on offshore drilling rather than on oil pollution from tankers. A more realistic appraisal might be to ask what the best way is, ecologically, to obtain the needed oil. For example, the potential drilling along the east coast of the United States has drawn considrable opposition from people concerned about the environment. But, offshore drilling in the United States has been *relatively* safe. From 1964 to 1971 there were 16 major spills from 10,234 producing wells. The oil released in the 8 years was about 46,000 tons; this number, although it could be lowered by stronger government regulation, is less than twice that spilled by the *Argo Merchant* and only a small fraction of that spilled by the *Amoco Cadiz*. An offshore drilling program with buried pipelines (a relatively safe way of transporting oil) and inshore refineries would in many instances be ecologically several times safer than bringing oil in by tankers. The best alternative, of course, would be to reduce our use of oil, and that is happening; nevertheless, offshore drilling will still be necessary.[155]

In addition, offshore drilling platforms provide beneficial habitats for fish. One explanation for the increased catch of fish in the Gulf of Mexico is the presence since 1947 of drilling platforms—increasing the fish catch from 300 million lbs. per year to 1.62 billion lbs. per year.[156] However, the fishing benefits such as have occured in the Gulf of Mexico may be counterbalanced in other parts of the world. For example, the extensive North Sea oilfields run through some of the world's richest fisheries. In this area, the oil industry may present a clash of interests with both the fishing industry and environmentalists.[157]

One other possible source of oil pollution in the offshore areas is from deepwater ports. Oil tankers have been increasing in size to where the supertankers or Very Large Crude Carriers (VLCCs) now range from 100,000 to 500,000 dwt, exceed one thousand feet

154. ROSS 1982, *supra* note 78, at 455.

155. *Id.* at 455 (emphasis original).

156. ROSS 1977, *supra* note 43, at 341-42.

157. *See* Johnston, *Mechanisms and Problems of Marine Pollution in Relation to Commercial Fisheries*, in MARINE POLLUTION 102-03 (R. Johnston ed. 1976).

in length, and require drafts of ninety feet or more.[158] With the exception of the Puget Sound area on the Pacific coast and several inlets in Maine on the Atlantic coast, no United States ports have the draft to accommodate VLCCs.[159] As a result, the concept of deepwater ports was initiated to offload VLCCs in ocean depths in excess of one hundred feet via docking at an artificial buoy or artificial island connecting to floating hoses.[160] Several provisions of the LOS Convention could apply to deepwater ports. If these ports are located in historic bays[161] (which do not have sufficient depth for supertankers in the United States but which may be adequate in other countries), any oil spills would be in internal waters as defined by Articles 8 and 10 of the LOS Convention.[162] As such they would probably constitute land-based pollution. Article 207 requires that: "States shall adopt laws and regulations to prevent, reduce and control pollution of the marine environment from land-based sources including rivers, estuaries, *pipelines and outfall structures*, taking into account internationally agreed rules, standards and recommended practices and procedures."[163] This Article would appear to apply to deepwater ports, which will utilize floating or submerged pipelines and outfall structures (artificial buoys or artificial islands).[164] Article 208 establishes coastal State jurisdiction over pollution from offshore installations,[165] but once again questions arise involving the vessel-source provisions.[166] Since oil spills at a deepwater port would almost invariably involve a VLCC, the vessel-source pollution provisions in Article 211, Paragraph 3 also apply.[167]

> States which establish particular requirements for the prevention, reduction and control of pollution of the marine envi-

158. Note, *Deepwater Port Act of 1974: Some International and Environmental Implications*, 6 GA. J. INT'L & COMP. L. 535, 536 (1976) [hereinafter cited as *Deepwater Ports*].

159. *Id.*

160. *Id.*; *see* Anderson, *supra* note 102, at 1035-49.

161. An historic bay is considered part of a State's internal waters, although its mouth is too wide for it to be so considered under international law. The basis for this is the State's "historic" practice of controlling all activities within that bay. In this respect, a long-standing claim by a State to the right to control a bay will outweigh international legal standards based on geography. *See* B. BRITTIN, INTERNATIONAL LAW FOR SEAGOING OFFICERS 78 (4TH ED. 1981).

162. LOS Convention, *supra* note 14, arts. 8, 10.

163. *Id.* art. 207 (emphasis added).

164. *See Deepwater Ports*, *supra* note 158, at 536.

165. LOS Convention, *supra* note 14, art. 208, para. 1.

166. *See supra* notes 134-135 and accompanying text.

167. LOS Convention, *supra* note 14, art. 211, para. 3.

> ronment as a condition for the entry of foreign vessels into their ports or internal waters or for *a call at their off-shore terminals* shall give due publicity to such requirements and shall communicate them to the competent international organization.[168]

Accordingly, Article 211 is relevant to deepwater ports and it allows for national regulations which comply, impliedly if not expressly, with the guidelines of IMCO, the appropriate international organization. Since this provision is appropriate and is positioned in a place of priority over subsequent paragraphs relating to regulation of vessel-source pollution in the territorial seas and economic zones, it appears to govern pollution from deepwater ports in internal waters, territorial seas (out to twelve miles), or even in economic zones (beyond twelve miles).[169] Of course, it is unlikely under the technology of the early 1980's that deepwater ports will be situated beyond twelve miles at sea. But considering that the United States, which still has a three mile territorial limit, will be one of the first countries using deepwater ports, it is conceivable that a deepwater port might be situated in the United States economic zone. In such a case, Article 211, Paragraph 3 would still be one of the controlling provisions in the LOS Convention.[170] Naturally, these problems can be avoided by careful planning and siting of deepwater ports. In addition, it should be noted that each of these provisions relating to deepwater ports establishes pollution jurisdiction in the coastal State.

One caveat to the transportation of oil and the development of offshore oil is that oil pollution is especially virulent in Arctic and Antarctic waters. "Oil pollution in Arctic [and Antarctic] waters would be more persistent and of more serious consequences than in warmer regions because degradation and evaporation is slower at lower temperatures."[171]

> For many arctic drilling sites, an accidental blowout could continue to discharge oil for a full year, because many arctic obstacles to the drilling of a relief well would prevent quick control of the blowout. While the technology to clean up an oil spill anywhere is still primitive, no equipment or knowledge exists to remove oil from arctic water and ice. After an offshore oil spill,

168. *Id.* (emphasis added).

169. *See id.* art. 211, paras. 3-5.

170. *Id.* art. 211, para. 3.

171. MARINE ENVIRONMENT, *supra* note 28, at 17; *see* Bilder, *supra* note 105, at 4-5; M'Gonigle, *Unilateralism and International Law: The Arctic Waters Pollution Prevention Act*, 34 U. TORONTO FAC. L. REV. 180 (1976).

> the minute rate of decomposition of hydrocarbons in cold areas would make arctic oil pollution all but permanent.
>
> Furthermore, a large discharge of oil in arctic waters could destroy vast quantities of irreplaceable natural resources. One arctic offshore spill of sizeable proportions could kill astronomical numbers of nesting geese, swans, ducks, terns, gulls, shore birds, etc., and might drive a number of species to the verge of extinction. Oil spreading beneath arctic ice could eradicate entire populations of seals, walruses, polar bears, and whales by congealing to block their breathing holes in the ice.[172]

Moreover, the effect of oil pollution on krill has been found to be particularly damaging.[173] Krill are perhaps the most basic link in the ocean food chain.[174] Any significant damage to the krill population would have serious effects on all marine life.[175] For these reasons, offshore development and transportation of oil need to be closely monitored, but not via unilateral extensions of jurisdiction.

b. Effects of Oil Pollution. "Marine plants and animals also produce hydrocarbons, but generally these differ from petroleum hydrocarbons in some important respects."[176] Some petroleum hydrocarbon compounds are toxic to marine ecosystems, but marine organisms can incorporate these compounds into their systems.[177] This incorporation process "has some beneficial effect in providing a slow, gradual clean up of an oil spill, but it has the associated short term problem of incorporation of petroleum hydrocarbons into the food chain."[178] While there is little evidence to suggest that petroleum concentrates in the food chain as DDT does, petroleum can: (1) disturb the food chain, (2) taint the taste of seafood such as shellfish, (3) befoul marine animals with coats of oil and destroy their natural repellent effects, (4) interfere with the reproductive capabilities of sea life, (5) disrupt the behavior of marine organisms, and (6) kill marine organisms via relatively low concentrations of hydrocarbons.[179] However, organisms which initially

172. Wood, *supra* note 52, at 554.

173. U.S. DEP'T ST., FINAL ENVIRONMENTAL IMPACT STATEMENT ON THE NEGOTIATION OF AN INTERNATIONAL REGIME FOR ANTARCTIC MINERAL RESOURCES, ch. 6, at 23-24 (1982).

174. *Id.*

175. *Id.*

176. MARINE ENVIRONMENT, *supra* note 28, at 15.

177. *Id.*

178. *Id.*

179. *See id.* at 15-16; Clingan, *Law Affecting the Quality of the Marine Environment*, 26 U. MIAMI L. REV. 223, 225 (1971) [hereinafter cited as Clingan]; Wood, *supra* note 52, at 550-52. *See also* MARINE POLLUTION AND SEA LIFE (M. Ruivo ed. 1973) [hereinafter cited as SEA

survive the concentrations of hydrocarbons to which they are exposed "seem to be able to purge themselves of much of the oil."[180] Nevertheless, it is generally accepted that "gallon for gallon, oil is one of the most persistent and destructive pollutants found in the environment in large quantities."[181]

In one of the most comprehensive investigations into a single oil spill event, researchers at the Woods Hole Oceanographic Institution found that as a result of the spill: "(1) there was severe local mortality of the plants and animals of the intertidal marsh and subtidal soft-bottom communities; (2) impacted communities required years for recovery; and (3) the oil was persistent, especially in the marsh areas which served as a source of recontamination by continuously oozing oil."[182] Even after several years, traces of oil could still be found in those plants and animals which were in the oil spill area.[183] For at least seven years after the oil spill, the sublethal effects of chronic oil pollution were still present.[184] In addition, the destruction of the marsh grass by the oil spill reduced the effectiveness of the marsh as: (1) a nursery area for marine life, (2) a purification system for runoff water, and (3) a land stabilization mechanism.[185]

"Oil slicks have been observed in almost all parts of the ocean and water birds, contaminated with oil, drift onto beaches far removed from oil-producing areas."[186] Since oil damages the feathers of water fowl, they are particularly susceptible to death as a result of oil.[187] Another aspect of oil pollution involves tar residues in the form of pellets, balls, or globs which are found on many beaches of the world.[188] "They present more of an aesthetic than a biological problem and are often colonized with marine life . . . ."[189]

The toxicity of oil increases in the series of paraffins, naph-

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LIFE]; OFFICE RESEARCH & DEVELOPMENT, U.S. ENVTL. PROTECTION AGENCY, ENVTL. OUTLOOK 1980 494, 494 (1980) [hereinafter cited as 1980 OUTLOOK].

180. MARINE ENVIRONMENT, *supra* note 28, at 16.

181. Anderson, *supra* note 102, at 990-92.

182. 1980 OUTLOOK, *supra* note 179, at 494.

183. *Id.*

184. *Id.*

185. *Id.*

186. Cowell, *supra* note 28, at 359.

187. *See* Bourne, *Seabirds and Pollution*, in MARINE POLLUTION 403, 406-07, 409-43 (R. Johnston ed. 1976); Cowell, *supra* note 28, at 364-69; Payne, *supra* note 90, at 84.

188. Cowell, *supra* note 28, at 364-69.

189. *Id.*; *see* Wood, *supra* note 52, at 550-51.

thenes and olefins to aromatics, and within each series the smaller molecules are more toxic than the larger molecules.[190] Oil pollution has significant deleterious effects on: (1) salt marshes, [191] (2) rocky shore ecosystems,[192] (3) sandy and muddy shore ecosystems,[193] (4) sediments in general,[194] (5) littoral animals,[195] (6) fisheries,[196] and (7) the high seas.[197] With regard to the effect of oil pollution on humans, there is some evidence that oil pollution leads to health risks. "Various kinds of carcinogenic hydrocarbons including 3,4-benzpyrene and some 1,2-benzanthracenes have been found in coastal bottom deposits, plankton and marine animals. Suspected sources of such carcinogenic materials include crude oils, combustion products from coal and oil, terrestrial runoff, and the *in situ* synthesis by bacteria and phytoplankton."[198] While carcinomas have been found in Baltic eels and bottom-feeding fish (near an oil refinery),[199] "there is no conclusive evidence in the literature that spilt oil can produce malignant growths in marine animals."[200] In summary, it should be noted that "while oil pollution does have an effect upon the marine ecosystems and . . . [while] more measures must be taken to reduce the incidence of oil spillage into the sea, nevertheless its chief problem is the aesthetic revulsion to the more persistent but virtually non-toxic fractions that are an all too familiar sight on the world's beaches."[201]

2. *Liquefied Natural Gas.*

a. *Classification by Origin.* Natural gas is usually found in oil-producing areas, but deposits of natural gas may be found without the presence of recoverable oil. Since natural gas is usually present in oil fields and usually provides the pressure for forcing oil to the surface, oil and gas have almost become one term.[202] With regard to the law of the sea, the major issues involving natural gas are

190. Cowell, *supra* note 28, at 369.
191. *Id.* at 371-73; *see* Cole, *supra* note 129, at 74.
192. Cowell, *supra* note 28, at 373.
193. *Id.* at 375-76.
194. *See* Cole, *supra* note 129, at 74.
195. Cowell, *supra* note 28, at 379-83.
196. *Id.* at 388-89; *see* Cole, *supra* note 129, at 74-75. *See also* SEA LIFE, *supra* note 179.
197. *See* Cowell, *supra* note 28, at 354-89; Wood, *supra* note 52, at 550-52.
198. Cowell, *supra* note 28, at 389.
199. *Id.* at 390.
200. *Id. Contra*, Anderson, *supra* note 102, at 992.
201. Cowell, *supra* note 28, at 395.
202. *See generally* Johnston, *supra* note 157, at 110-19.

those relating to liquefied natural gas (LNG), which is sometimes less properly referred to as liquid natural gas.[203] LNG is natural gas which has been cooled in stages until it reaches −260° Fahrenheit, at which point it becomes a colorless liquid that is 1/600 the volume of the original gas.[204] Due to this reduction in volume, LNG is relatively economical to transport via specially constructed ships.[205]

As much as "15 percent of the nation's gas may soon be imported . . . ."[206] Ship transport of LNG appears to be the most efficient way to move natural gas from production areas to consuming nations.[207] The ships used to transport LNG to the United States include nine ships of the El Paso Company and its subsidiaries.[208] Each of these ships has a cargo capacity of 125,000 cubic meters of LNG, which is equal to 2.5 billion cubic feet of gas, enough to supply the annual needs of 17,000 customers.[209] The main shipping port is Arzew in Algeria.[210] The Hassi R'Mel field in Algeria contains "reserves that total more than one-fourth of the proven reserves in the United States, including Alaska."[211] The east coast of the United States has one receiving terminal at Cove Point, Maryland, which is on the Chesapeake Bay, and another on Elba Island near Savannah, Georgia.[212] A proposed Pacific coast terminal site is Little Cojo, California, which is near Point Conception.[213]

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203. *See* R. WOOLER, MARINE TRANSPORTATION OF LNG AND RELATED PRODUCTS (1975); STAFF OF SENATE COMM. ON COM., SCI., AND TRANSP., 95TH CONG., 2D SESS., LIQUEFIED NATURAL GAS: SAFETY, SITING, AND POLICY CONCERNS iii, v, vii (Comm. Print 1978) [hereinafter cited as LNG REPORT]; Greenwald, *LNG Carrier Safety: A Guide to the System of Federal Regulation*, 9 J. MAR. L. & COM. 155 (1978); Wilson, *Perspectives on LNG Terminal Siting*, 9 NAT. RESOURCES LAW. 535 (1976); Born, *LNG Hazards*, BARRON'S, Nov. 19, 1979, at 11; Cockburn & Ridgeway, *Liquid Natural Gas Tankers Rouse Fears of Catastrophe*, Richmond Times-Dispatch, Feb. 20, 1977 (Parade Magazine), § C, at 23 (which refers to LNG as "Liquid natural gas") [hereinafter cited as Cockburn]; Katz & West, The Overall Problem-Risk/Benefit for LNG Shipping and Storage, (Paper presented at the Engineering Foundation Conference on Risk/Benefit Methodology and Application, Asilomar, California, Sept. 21-26, 1975—on file with Prof. Donald Katz, Univ. of Michigan) [hereinafter cited as Katz].

204. LNG REPORT, *supra* note 203, at 2.

205. *Id.*

206. *Id.* at 2.

207. Cockburn, *supra* note 203, at 23.

208. LNG REPORT, *supra* note 203, at 2.

209. *Id.*

210. *Id.*

211. *Id.* at 1-4.

212. *Id.* at 2, 4. Greenwald, *supra* note 203, at 155.

213. Born, *supra* note 203, at 11.

Most proposed sites for a California terminal have met considerable opposition. Concerns for public safety include: (1) the safety of the LNG vessels while in transit, (2) the degree of safety involved in unloading and revaporizing LNG, (3) the degree of safety necessary for storing and distributing LNG, and (4) the degree of protection which can be built into LNG facilities to make them substantially able to resist earthquakes.[214] All eighty-two sites originally selected for consideration by the California Coastal Commission were found unacceptable.[215] However, on July 31, 1978, the California Coastal Commission granted conditional approval to the Point Conception site.[216] Final approval was predicated upon proof that earthquake faults in the area constituted an acceptable risk.[217] Nationally, LNG is regulated by the Department of Energy under a set of confusing and disorganized rules.[218]

To the extent that the LNG might escape from loading or unloading facilities, including processing and storage facilities, it should probably be considered to be land-based pollution under Article 207 of the LOS Convention.[219] However, when LNG is spilled it rapidly changes into a gas[220] and thereby metamorphoses into "air-borne pollution." The question then arises as to whether the gas is still governed by Article 207 or whether it is governed by Article 212 which regulates air-borne pollution.[221] This question appears to involve a hypothetical case *primae impressionis.* The history of the law of the sea negotiations is quite nebulous in the area of the air-borne pollution provisions, but the general trend appears to have been the regulation of continuous air-borne pollution[222] as distinguished from occasional accidental releases. The accidental release must also be of relatively minor significance when viewed in the context of the overall world environment. Thus, the vaporization of LNG from an accidental spill would comply with these con-

214. Lutz, *Energy, Environment and LNG: Perceptions and Perspectives of Kaleidoscope Issues*, 9 PEPPERDINE L. REV. 11, 20 (1981).

215. *Energy in the Eighties—Energy Law Symposium: LNG in Southern California*, 9 PEPPERDINE L. REV. 1, 6 (1981).

216. *Id.*

217. *Id.*

218. Smith, *The Regulation of Natural Gas Liquids: An Introduction of DOE Approaches and Problems*, 21 S. TEX. L.J. 98, 112 (1980).

219. *See* LOS Convention, *supra* note 14, art. 207.

220. LNG REPORT, *supra* note 203, at xii, 41.

221. *See* LOS Convention, *supra* note 14, arts. 207, 212-13, 222.

222. *See generally* Johnston, *supra* note 157, at 110-11.

ditions,[223] while radioactive fallout from an accidental nuclear detonation or the melt-down of a reactor core would not.[224] In addition, a nuclear accident would generally be governed by more specific international instruments.[225]

Since most expected LNG accidents will involve a tanker,[226] the vessel-source pollution provisions in Article 211 of the LOS Convention will probably be the provisions most used to govern LNG spills.[227] In this instance, LNG accidents can be usefully compared with spills.[228] This comparison would include LNG accidents involving loading or unloading at port facilities, and even at the LNG equivalent of deepwater ports.[229] However, the volatility of LNG would in all likelihood quickly change an LNG spill into a maritime accident. Thus, LNG spills should be governed by land-based pollution provisions when they occur at land-based storage facilities; otherwise, they should be treated much like vessel-source oil spills. Similarly, the general escape of natural gas which is concomitant to oil exploration and production activities, including offshore development, should generally be treated under the guidelines for accidents involving oil.[230] There is a large amount of natural gas which is released into the atmosphere or burned-off at oil fields in the Western Hemisphere. The United States could more profitably utilize this wasted natural gas and forego importation of dangerous LNG from such distant shores as Algeria.

b. Effects of Natural Gas Pollution. The escape of natural gas into the atmosphere, which generally occurs during the development of oil fields and during related accidents, appears to constitute a relatively small difficulty when viewed in the context of the overall world problem of pollution. Once natural gas escapes from land-based or offshore development facilities, it theoretically becomes air-borne pollution, but until this escape of gases is proved to

223. *See* LNG REPORT, *supra* note 203, at 41.

224. *See generally* Morris, *supra* note 139, at 316-18.

225. *See, e.g.*, Nuclear Test Ban Treaty, *done* Aug. 5, 1963, 14 U.S.T. 1313, T.I.A.S. No. 5433, 480 U.N.T.S. 43 (entered into force Oct. 10, 1963); Nuclear Non-Proliferation Treaty, July 1, 1968, 21 U.S.T. 483, T.I.A.S. No. 6839, 729 U.N.T.S. 161 (entered into force Mar. 5, 1970); Seabed Arms Control Treaty, Feb. 11, 1971, 23 U.S.T. 701, T.I.A.S. No. 7337 (entered into force May 18, 1972).

226. *See* LNG REPORT, *supra* note 203, at 12, 79-85.

227. *See* LOS Convention, *supra* note 14, art. 211.

228. *See supra* notes 102-132 and accompanying text.

229. *See supra* notes 158-170 and accompanying text.

230. *See supra* notes 102-111, 158-170 and accompanying text.

have an effect on the atmosphere or to contribute to acid rain,[231] it should probably be dealt with as land-based pollution and as pollution from offshore exploitation—similar to oil pollution.[232]

By contrast, the inefficient burning of natural gas containing sulfur does contribute to air-borne pollution, and as such, it is governed by Articles 212 and 222 of the LOS Convention.[233]

> The inefficient combustion of sulphur-containing gas and oil both add significantly to air pollution in a number of different ways . . . . SO_2 [sulfur-dioxide] is not thought to be significant for marine life. Both, however, also contribute to the emission of particulates and hydrocarbons, adding to the existing burden on the seas and oceans.[234]

The conclusion that SO_2 does not significantly affect marine life impliedly contradicts the earlier conclusions involving air-borne pollution caused by petroleum hydrocarbons.[235] Although the earlier conclusions were not directly related to pollution by SO_2, the implication was that petroleum hydrocarbons and pollutants related to the inefficient burning of petroleum hydrocarbons had a significant effect on the marine environment.[236] The problem is that definitive scientific evidence precisely relevant to a particular pollutant in a particular medium is often lacking. Therefore, there must be some extrapolation from the preliminary scientific studies. This situation highlights the need for a maximum amount of freedom for marine scientific research.

"Natural gas is made up of a number of hydrocarbons C_1 to C_5 with the normal paraffins methane to pentane predominating."[237] Many oil fields burn-off excess natural gas, contributing to air-borne pollution and acid rain. The failure of the U.S.-Mexican negotiations for the sale of natural gas to the United States dramatically evidenced this fact when Pemex decided to continue burning-off its natural gas (as a total loss) rather than sell it at what the Mexican officials considered to be an unfavorable price.[238] Other than this type of pollution and the traditional fire hazards associ-

231. *See generally Comment on Acid Rain*, *supra* note 53, at 22.
232. *See supra* notes 27-172 and accompanying text.
233. *See* LOS Convention, *supra* note 14, arts. 212, 222.
234. Johnston, *supra* note 157, at 110.
235. *See supra* notes 61-77 and accompanying text.
236. *See supra* notes 73-75 and accompanying text.
237. Johnston, *supra* note 157, at 110.
238. *See* Pelham, *U.S.-Mexican Negotiations Planned on Natural Gas*, 37 CONG. Q. 318, 318 (1979); *Mexico's Reluctant Oil Boom*, BUS. WEEK, Jan. 15, 1979, at 64, 64.

ated with the accidental release of natural gas into the atmosphere, land-based pollution involving natural gas does not appear to be a significant problem, and it did not command much special attention during the law of the sea negotiations. Basically, these types of pollution are under the direction and control of the countries in which the pollution is generated.[239]

In the area of offshore development, the accidental release of natural gas from the ocean floor appears to have minimal effects on fish, phytoplankton, and zooplankton.[240] "Underwater release of natural gas creates locally high concentrations of these paraffins [methane to pentane] dissolved under pressure, which can be toxic in the immediate plume of released gas, but are quickly dispersed. These gases are capable of being used by some micro-organisms as a carbon source . . . ."[241] Accordingly, the ramifications of an accidental release consisting solely of natural gas during offshore development appear to be minimal. A release of natural gas in combination with an oil spill obviously creates larger problems, but the environmental ramifications in such a case are largely related to the discharge of oil as distinguished from natural gas. The Pemex oil well blowout in Campeche Bay in 1979 confirms these conclusions.[242]

With regard to LNG, there are special problems. "The construction and operation of LNG facilities impact on air and water resources, preempt use of land, and like deep water ports and most refineries, affect valuable coastal and estuarine areas."[243] More specifically, LNG facilities may provide a hazard to humans in the form of possible explosions.[244] Expert testimony before the U.S. Senate Committee on Commerce, Science, and Transportation has indicated that "[c]onsiderable research has been done on the possibility of unconfined mixtures—as might occur in a large LNG spill—exploding when ignited. However, no evidence that this kind of explosion or detonation will occur has ever been found, and thus there is a general consensus that this is not a credible haz-

239. *See* Greenwald, *supra* note 203, at 159; LOS Convention, *supra* note 14, arts. 207, 212-13, 222.

240. Johnston, *supra* note 157, at 110-11.

241. *Id.* at 110.

242. *See* Beck, *supra* note 143, at 24; *Oil Slick*, *supra* note 143, at 50; *Oil Spill Wrangle*, *supra* note 143, at 26.

243. Wilson, *supra* note 203, at 535.

244. Cockburn, *supra* note 203, at 23.

ard."[245] This expert testimony appears to ignore the results of a 1944 LNG spill in Cleveland, which, among other things, involved explosions from unconfined LNG.[246]

> On Oct. 20, 1944, in Cleveland, Ohio, 2 million gallons of liquid natural gas burst from two storage tanks belonging to the East Ohio Gas Co. and created a firestorm. *Liquid gas flowed down the streets* and into the sewers. The slightest spark exploded it. Manhole covers sailed into the air and fell like bombs on the fleeing crowds. So intense was the heat that birds above the city burned alive as they flew. The streets became rivers of flame. Houses exploded. In the end, 29 acres of homes and stores were gutted and 131 people lost their lives.[247]

Although the explosions in the Cleveland spill may theoretically have been from confined LNG, the Cleveland experience demonstrates that a land-based LNG spill is going to: (1) occur under less than laboratory conditions, (2) involve LNG running into confined spaces and then exploding, (3) involve the igniting of unconfined LNG in flashes which are roughly equivalent to explosions, and (4) cause a potentially large amount of property damage and loss of human life.[248]

With regard to the transport of LNG via supertankers, testimony before the Committee indicated that during the last 30 years, "[o]ver 2,000 shipments of LNG have been made without incident."[249] However, the possibilities for a marine disaster are increasing with the growth of marine traffic; for example, each year over four thousand ships move through the Chesapeake Bay near the Cove Point LNG terminal.[250] A possible spill of LNG onto water involves a different type of risk according to the Committee testimony.

> Another type of explosion occurs when LNG is accidentally spilled on water. It is an unusual phenomenon involving vaporization at an extremely high rate followed by an air blast—and this occurs without the fuel combusting. Research studies have demonstrated, however, that this phenomenon occurs only when the content of the higher hydrocarbons, such as ethane, is greater than that present in most all LNG that is shipped or stored.

245. LNG REPORT, *supra* note 203, at 41.
246. *See id.* at 123.
247. Cockburn, *supra* note 203, at 23 (emphasis added); *see* LNG REPORT, *supra* note 203, at 123.
248. *See* Cockburn, *supra* note 203, at 23.
249. LNG REPORT, *supra* note 203, at 122.
250. *Id.* at 12.

> However, even when such explosions do occur, their energy content is relatively small.[251]

Allegedly, the vaporization of LNG after it is spilled results in a fire if it is somehow ignited.[252] "If the vapor is not ignited, it will form a cloud that will move downwind,"[253] and this vapor cloud may be ignited at any time before it is dispersed by the natural turbulence of the air.[254]

> As for a postulated accidental release of the total cargo of an LNG tanker, the fire hazard region would be about one-half mile. If an entire cargo were to be suddenly discharged onto the water, the time duration of the fire hazard would be approximately 30 minutes.[255]

These statements are not only misleading, but also deceptive. They attempt to downplay the probability, extent and overall danger of potential LNG spills. Given the magnitude of the Cleveland accident and the potential volatility of LNG, it is sophomoric to ask the public not to allow for an LNG explosion or even expect an LNG spill/cloud to ignite. Almost by definition, a collision between two vessels is going to involve some sparks, and "the liquid gas tanks in Cleveland held only a small fraction of the amount carried by a modern tanker, which ranges from about 33 to 42 million gallons."[256] Even more disturbing is the allegation that the Senate Committee testimony was inaccurate because LNG can explode simply by coming into contact with water.

> In 1970 the U.S. Bureau of Mines mounted a brief experiment. A small quantity of liquid natural gas was dropped into an aquarium, which promptly blew up. Later the liquid gas was dropped into a pond, with equally explosive results. The bureau concluded in a report that no assurances can be offered "that these explosions could not scale up to damaging proportions in a massive spill."[257]

While estimates that the explosion of an LNG tanker at sea would equate to the explosive force of the 1883 volcanic explosion of Krakatoa[258] are exaggerated, the U.S. Coast Guard, like the Senate Committee, may have underestimated the danger of such an

251. *Id.* at 41.
252. *Id.*
253. *Id.*
254. *Id.*
255. *Id.* at 79.
256. Cockburn, *supra* note 203, at 23.
257. *Id.*
258. *Id.*

incident. The Coast Guard evaluates substances transported by water and focuses on four hazards: (1) fire; (2) health (effecting skin, eyes or inhalation);[259] (3) pollution that is toxic to humans or the aquatic environment, or aesthetically offensive; and (4) reactivity (that is, the susceptibility of the substance to react chemically with water or other substances).[260] These hazards are ranked from zero to four—with zero indicating no hazard and four indicating a maximum hazard. "On this rating scale, natural gas (or methane) was ranked zero, with a finding that *it presents no health, environmental, or reactive hazards.*"[261] However, the fire hazard of natural gas was rated as four when within its flammability range (five to fifteen percent of a gas-air mixture).[262] These ratings apply to natural gas per se, and perhaps they should be modified within the context of LNG. For example, LNG freezes human skin on contact and may asphyxiate workers when it evaporates.[263] Although natural gas is currently rated at zero, the health risk of LNG necessitates a separate rating, probably between three and four.[264]

The answer to many of these problems appears to be the maintenance of at least five miles[265] distance between LNG tankers and any other ships—and even greater distances from population centers. LNG tankers and their crews may assume the risk of incinerating or exploding themselves, but that risk cannot be assumed by other people exercising the right of innocent passage. While at sea, any leak of LNG may asphyxiate the crew. Therefore, any provisions for immediately reporting LNG leaks, similar to those France imposed for oil leaks following the *Amoco Cadiz* oil spill,[266] may be inappropriate. Basically as a result of the *Amoco Cadiz* accident,[267] LOS Convention Article 211, Paragraph 7, now requires "prompt notification to coastal States, whose coastline or related interests may be affected by incidents, including maritime casualties, which

259. LNG will freeze skin on contact and cause asphyxiation of workers when it evaporates. LNG REPORT, *supra* note 203, at 41.

260. Greenwald, *supra* note 203, at 159.

261. *Id.* (emphasis added).

262. *Id.*

263. LNG REPORT, *supra* note 203, at 41.

264. Greenwald, *supra* note 203, at 159.

265. *See generally* LNG REPORT, *supra* note 203, at 79.

266. *See* Oxman, *The Third United Nations Conference On The Law Of The Sea: The Seventh Session (1978)*, 73 AM. J. INT'L L. 1, 1, 25 (1979).

267. *See id.* at 25 n.81. Article 212, Paragraph 6, in the Informal Composite Negotiating Text (ICNT) equates to article 211, Paragraph 6, in all subsequent negotiating texts.

involve discharges or probability of discharges."[268] Thus, while an LNG leak must be reported to foreseeably affected countries, the dangerous nature of LNG may hypothetically prevent such warnings from occurring. This situation gives rise to the imaginary horrible of an asphyxiated LNG crew floating in an explosive LNG cloud and drifting into a well traveled area such as the English channel.

While this scenario is perhaps unlikely, it emphasizes that individual companies should initiate self-imposed conditions for providing compensation for property damage and loss of human life. This compensation should be modeled on the international instruments providing recovery for damage from oil pollution, for example TOVALOP and CRISTAL.[269] In addition, IMCO needs to begin formulating regualtions in this area. Indeed, Article 211 of the LOS Convention already gives IMCO jurisdiction to regulate the kind of accidents which are likely to occur with LNG tankers.[270] If the LNG industry and IMCO do not provide remedies, the first well-publicized accident may create a degree of public concern that would instigate a seizure of jurisdiction from where it belongs, and result in the imposition of potentially onerous standards by outside sources.

In addition, LNG loading and unloading facilities and even operations and storage facilities need to be sited away from population centers.[271] The offshore siting of LNG facilities may solve many problems, and is a proposal that can be profitably compared to the offshore siting of floating nuclear power plants.[272]

> The concept of LNG terminals offshore is beginning to receive increased attention by Federal, State, and industry officials. The potential safety hazards to onshore areas from LNG operations may be lessened by moving part or all of the LNG receiving terminal and its associated storage tanks and regasification units many miles offshore. In the event of a spill or other mishaps, those miles of ocean might constitute an effective buffer, giving a combustible or explosive gas cloud more opportunity to disperse before reaching any populated areas. *Environmental damage of a spill many miles from shore may be minor because of*

268. LOS Convention, *supra* note 14, art. 211, para. 7.
269. *See supra* notes 108-111 and accompanying text.
270. LOS Convention, *supra* note 14, art. 211.
271. *See* Katz, *supra* note 203, at 43.
272. *See* Morris, *supra* note 139, at 299.

the quick evaporation of LNG.[273]

Thus, there are many advantages to siting LNG facilities in offshore areas. The United States, in particular, needs the economical energy that the LNG transports can provide,[274] and with long-term planning the safety and environmental problems can be remedied.

B. Organicides and the Organic Poisons

Every year approximately two million new artificial chemical compounds are invented, of which it is estimated that one thousand are introduced into general use. As of 1981, over ten thousand of these synthetic organic chemicals had already been incorporated into industrial, commercial and personal use.[275] These chemicals are used as fuels, lubricants, plasticizers, food additives and preservatives, and they can be found in cosmetics, drugs, aerosol propellants and apparel.[276]

These synthetic compounds are harmful to many life forms, including man, as many of them have been found to be potential carcinogens.[277] Statistics reveal that one out of every four Americans will contract cancer.[278] Therefore, sixty million Americans will be stricken with cancer, and the disease will be fatal in approximately sixty-seven percent of these cases.[279] During 1969, cancers caused 323,000 deaths in the United States; while by comparison, only 3300 deaths were caused by polio during its worst outbreak, and 292,000 Americans died during World War II.[280] Authorities estimate that environmental factors cause sixty to ninety percent of all cancers.[281] Unlike many poisons, carcinogens are typically latent for twenty to thirty years—the lag time comprising the difference between the initial exposure to a cancer-causing substance and the onset of the cancer.[282] Thus the long-term effect of pollution by

273. LNG REPORT, *supra* note 203, at 127 (emphasis added).

274. Cockburn, *supra* note 203, at 23.

275. Comment, *The Burden of Proof in Environmental and Public Health Litigation*, 49 UMKC L. REV. 207, 207 (1981) [hereinafter cited as *Proof in Environmental Litigation*].

276. *See generally* S. REP. NO. 1302, 94th Cong., 2d Sess.; H.R. REP. NO. 1697, 94th Cong., 2d Sess. (1976) *reprinted in* 1976 U.S. CODE CONG. & AD. NEWS 4491, 4539.

277. *See Proof in Environmental Litigation, supra* note 275, at 207.

278. Schulz, *Synthetics, Latent Risks and Governmental Response: The Case of Fluorocarbons and Stratospheric Ozone*, 5 ENVTL. L. REP. 50109 (1975).

279. *Id.*

280. *Id.*

281. Epstein, *Control of Chemical Pollutants*, 228 NATURE 816 (1970); *see also* SENATE COMM. ON COMMERCE, TOXIC SUBSTANCES CONTROL ACT, S. REP. NO. 698. 94th Cong., 2d Sess. (1976) *reprinted in* 1976 U.S. CODE CONG. & AD. NEWS 4491, 4496.

282. *See Proof in Environmental Litigation, supra* note 275, at 207.

organic poisons can be devastating.

Being generally unversed in intricate scientific terminology, international legal scholars often have a tendency to group the different organic poisons in various unscientific and confusing categories.[283] At the risk of adding to this confusion, the organic poisons should probably be subdivided into the following categories: (1) herbicides (including fungicides); (2) organochlorine pesticides (for example, chlorinated hydrocarbons); and (3) organophosphorus insecticides (including carbamate insecticides).[284]

The term pesticide can be confusing since it is often used to refer to all of the organic poisons as well as just those specifically used to kill animal pests. The use of the word pesticide as an overall term also implies that pests must include all plants and insects which constitute actual or imagined detriments to mankind and to mankind's associated developmental progress. However, plants, animals and insects are not always delimited as pests,[285] and this overall use of the term pesticide suggests a bias toward development without any regard whatsoever for environmental considerations. While this interpretation may appear to raise an issue which is *de minimus*, it should be noted that the United States Congress has overused this term, particularly in the titles of United States legislation. Since this term is confusing, overly broad and reflects a developmental bias, the term "pesticide" should be used to refer primarily to poisons utilized to kill animal pests. Accordingly, "herbicide" should refer to poisons used to destroy or inhibit plant growth, and "insecticide" should refer to poisons used to kill destructive insects.

Since all of these poisons are utilized to control organic life, the best overall laymen's term to describe them is organic poisons, or perhaps "organicides." From a scientific viewpoint, most of these poisons are carbon-based and are therefore referred to scien-

283. *See* MARINE ENVIORONMENT, *supra* note 28, at 5-7. *See generally* Clingan, *supra* note 179, at 226-28; Harvey, *DDT and PCB in the Atlantic*, OCEANUS, Fall 1974, at 18 [hereinafter cited as Harvey]; Johnston, *supra* note 157, at 65-78.

284. Johnston, *supra* note 157, at 65-73.

285. The primary definition of "pest" is an epidemic disease associated with high mortality, specifically a plague. Secondly, a pest is something resembling a pest in destructiveness, especially a plant or animal detrimental to man. WEBSTER'S NINTH NEW COLLEGIATE DICTIONARY 879 (9th ed. 1983). While animals such as rats could constitute a plague per se due to overpopulation (and could certainly transmit plagues), to equate nuisance "plants" with a plague by delimiting them as "pests" appears to be a misconstruction. At worst, plants would constitute an "annoyance," the third definition of "pest." *Id.*; WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY 1689 (3d ed. 1961).

tifically as organic poisons. New poisons which are not carbon-based will invariably be developed, and the term organic poisons should probably be reserved as a scientific term for the carbon-based poisons. Thus, the best policy would appear to involve using the term "organicide" or "organocide" to refer to manufactured poisons directed against organic life; that is, nuisance plants, animals and insects. The nonscientific subcategories would then be delimited as herbicides, pesticides and insecticides.

United States legislation in 1972 delimited organicides as economic poisons by defining them as follows:

> (a) the term "economic poison" means (1) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, weeds, and other forms of plant or animal life or viruses, except viruses on or in living man or other animals, which the Administrator shall declare to be a pest, and (2) any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant.[286]

However, organicide still appears to be an appropriate layman's term for economic poisons.

The first U.S. legislation in this area was the Insecticide Act,[287] which was enacted in 1910 and was designed to protect farmers from adulterated or misbranded insecticides and fungicides. The Insecticide Act was repealed by the Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (FIFRA),[288] which initiated a new system for regulating organicides. Prior to the FIFRA, the Food, Drug and Cosmetic Act of 1938 (FDCA)[289] had banned the sale of all foods which contained poisonous additives, except when those additives or residues were necessary or could not be avoided—in which case tolerance levels were established to protect the public health.[290] The FDCA was amended by the Pesticide Chemical Amendments of 1954 (Miller Amendment),[291] which prohibited the U.S. Department of Agriculture (USDA) from registering any poison which might leave a residue on or in an agricultural product until either a tolerance level was established or it could be shown

286. 7 U.S.C. § 135a (1976).

287. Act of Apr. 26, 1910, Pub. L. No. 61-152, 36 Stat. 331 (1910).

288. 7 U.S.C. § 121 *et. seq.* (1976).

289. 21 U.S.C. § 301 *et. seq.* (1976 & Supp. IV 1981)

290. *See id.* §§ 331a, 342a, 346, 346a.

291. Pub. L. No. 83-518, 68 Stat. 511 (1954) (codified in scattered sections of 21 U.S.C. §§ 301-392 (1976)); *see* 1972 U.S. CODE CONG. & AD. NEWS 3993, 3999.

that no residue would result from the poison's use.[292] In 1958 the Pesticide Research Act[293] provided funds to the Department of Interior (DOI) to research the effects of organicides on fish and wildlife.

From 1959 to 1971, the FIFRA and the FDCA were amended several times but the changes were not major.[294] In 1959 the FIFRA was amended to expand the term economic poisons to include defoliants, desiccants, nematocides and plant regulators.[295] This amendment highlights the previous definitional problems involved in delimiting pesticides vis-à-vis economic poisons vis-à-vis organicides. In 1960 the FDCA was amended to modify the labeling requirements involving post-harvest uses of organicides.[296] Due to increased public awareness of the dangers of organicides,[297] the FIFRA was again amended in 1964 to eliminate protest registrations which allowed manufactureres to market organicides even after the USDA had refused to register them.[298]

The next major legislation impacting on this area was the Occupational Safety and Health Act of 1970 (OSHA),[299] which established standards specifying various precautions, including the amount of time which was required before farm workers could reenter fields sprayed with organicides (known as re-entry standards).[300] However, the establishment of the Environmental Protection Agency (EPA) in 1970 transferred to the EPA: (1) the USDA's registration authority, (2) DOI's research authority, and (3) the Department of Health, Education and Welfare's (HEW) tolerance-setting authority.[301] Furthermore, OSHA's authority to es-

292. *See* 21 U.S.C. § 342 (1976).

293. Pub. L. No. 85-582, 72 Stat. 479 (1958).

294. ENVIRONMENTAL PROTECTION AGENCY, ENVIRONMENTAL PROTECTION: AN HISTORICAL REVIEW OF LEGISLATION AND PROGRAMS OF THE ENVIRONMENTAL PROTECTION AGENCY 76 (1983) [hereinafter cited as ENVIRONMENTAL REVIEW]; *see* 1972 U.S. CODE CONG. & AD. NEWS 3993, 3999-4000.

295. Pub. L. No. 86-139, 73 Stat. 286 (1959) (amending scattered sections of 7 U.S.C. §§ 135-135k (1947)).

296. Pub. L. No. 86-537, 74 Stat. 251 (1960) (amending 21 U.S.C. § 343 (1938)).

297. The Public awareness of the danger of organicides was largely prompted by Rachel Carson's book entitled *Silent Spring*. *See* R. CARSON, SILENT SPRING (1962); ENVIRONMENTAL REVIEW, *supra* note 294, at 76.

298. Pub. L. No. 88-305, 78 Stat. 190 (1964) (amending scattered sections of 7 U.S.C. §§ 135-135k (1947)).

299. 29 U.S.C. § 651 *et. seq.* (1976 & Supp. V 1981).

300. *See id.* § 655; ENVIRONMENTAL REVIEW, *supra* note 294, at 78.

301. ENVIRONMENTAL REVIEW, *supra* note 294, at 77.

tablish re-entry standards was transferred to the EPA in 1975.[302] Accordingly, since 1975 the EPA has exercized jurisdiction over all organicide regulation responsibilities: (1) guarantee of efficacy, (2) protection of the public health, (3) environmental protection, and (4) protection of farm workers.[303] In addition, a complete revision of the FIFRA occurred with the enactment of the major legislation currently dealing with organicides; namely, the Federal Environmental Pesticide Control Act of 1972 (FEPCA).[304]

Since 1972, organic poisons have been generally regulated by FEPCA,[305] which is implemented by the EPA.[306] FEPCA authorizes the EPA to regulate pesticides by requiring that all pesticide products must be registered before they can be sold, distributed, or delivered into commerce.[307] A pesticide is defined as including any substance intended for preventing, destroying, repelling or mitigating any pest and any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant.[308] The registration and re-registration data provided by the pesticide companies give the EPA the information necessary for evaluating the effects of pesticides.[309] The FEPCA explicitly conditions new or continued registration of a product upon the EPA's determination that the product does not cause "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide."[310] Thus, the FEPCA requires the EPA to undertake a risk-benefit analysis, and to make difficult trade-offs between the often conflicting objectives of protecting man and the environment from pesticide hazards, and realizing the economic advantages afforded by pesticide use.[311] The EPA may deny or approve a new registration of a pesticide,[312]

302. *Id.* at 78.

303. *Id.*

304. 7 U.S.C. §§ 136-136y (1976 & Supp. V 1981) (formerly the Federal Insecticide, Fungicide and Rodenticide Act (FEPCA)). The regulations for the enforcement of this act are found in Pesticide Programs, 40 C.F.R. § 162 (1982).

305. 7 U.S.C. §§ 136-136y (1976 & Supp. V 1981).

306. Note, *Pesticide Regulation: Risk Assessment and Burden of Proof*, 45 GEO. WASH. L. REV. 1066, 1066 (1977) [hereinafter cited as *Risk Assessment*]; Comment, *Pesticides: The Problem and the Solution*, 7 TEX. TECH. L. REV. 79, 79 (1975) [hereinafter cited as *Pesticide Problem*].

307. 7 U.S.C. § 136a(a) (1976).

308. *Id.* § 136(u).

309. *Id.* § 136a(c)(1)-(2); *see Risk Assessment*, *supra* note 306, at 1066.

310. 7 U.S.C. § 136a(c)(2)(D) (1976).

311. *Risk Assessment*, *supra* note 306, at 1066, 1070.

312. 7 U.S.C. § 136a(c)(5) (1976).

cancel an existing registration,[313] suspend a registration pending completion of cancellation proceedings[314] or classify a pesticide for general or restricted use.[315]

To assist the decision-maker in assessing the risk of pesticide use, the following list of factors has been suggested:

> 1. Extent of exposure: Absent restrictions, what number of people will be exposed to the substance?
> 2. Existence of particularly susceptible subgroups: Are there subgroups in an exposed population which would be particularly susceptible to harm?
> 3. Ability of citizens to protect themselves: Can the population as a whole or can the particularly susceptible subgroups protect themselves against the harm?
> 4. Threshold levels of exposure: Do exposure thresholds exist, delimiting the point at which adverse health effects are caused by the substance which is to be regulated?
> 5. Interaction of contaminants with each other: Different environmental contaminants may interact synergistically to increase the potential for harm beyond what generally would be expected if the sum of the different risks were simply added.
> 6. Reversibility: Is the disease process capable of being reversed?
> 7. Long latent periods: Diseases with a long latency period need special consideration, since if it is not restricted, it may take 20 or more years before the appearance of the projected illness.[316]

1. *Herbicides.*

The use of herbicides on a large scale did not develop until the 1940's.[317] "In biblical times such herbicides as ashes, common salts, and bittern were used,"[318] and in 1890 sodium arsenite became a popular weed killer.[319] "Since about 1925 sodium arsenite has been used rather extensively as an aquatic herbicide in lakes and farm ponds."[320] Other herbicides included borates, sodium chlorate,

313. *Id.* § 136d(a)-(b).
314. *Id.* § 136d(c).
315. *Id.* § 136a(d).
316. Karstadt, *Protecting Public Health from Hazardous Substances: Federal Regulation of Environmental Contaminants*, 5 ENVTL. L. REP. 50,165 (1975).
317. E.P.A. HAZARDOUS MATERIALS ADVISORY COMMITTEE, HERBICIDE REPORT 11 (No. EPA-SAB-74-001, May 1974) [hereinafter cited as HERBICIDE REPORT].
318. *Id.*
319. *Id.*
320. *Id.*

ammonium sulfamate and sulfuric acid.[321] The origin of the organic herbicides is "generally attributed to the development of 2,4-D in the early 1940's" but there were a few earlier organic herbicides.[322] The growth in the number of herbicides has been rapid. "In the period from 1950 to 1970, herbicide production increased from 20.25 million kilograms per year to 180 million kilograms, and the dollar value from 20 million to 50 million . . . ."[323]

It has been suggested that most herbicides "are stable in soil to a much lesser extent than DDT and there are no records of herbicides causing serious damage to the marine environment."[324] This statement is misleading since it implies that herbicides do not damage the marine environment, whereas in reality it highlights the fact that there are few studies in this area. Those studies that exist are perhaps somewhat speculative and limited in scope.[325] Apparently, a few tests have revealed that "marine phytoplankton have responded to herbicides in much the same way as unicellular freshwater plants."[326] Among others, the herbicides diquat and paraquat have been tested on phytoplankton cultures, and the paraquat demonstrated an especially marked effect.[327] Paraquat received increased attention in 1978 when it had supposedly contaminated large amounts of marijuana being illegally shipped into the United States from Mexico.[328] In view of the new research which will be prompted by this type of publicity, it is too early to make any definitive conclusions to the effect that "[h]erbicide pollution is not a significant threat apart from the risk of a cargo of herbicide being lost at sea or in an estuary which might well create extensive local damage to the phytoplankton and attached algae."[329] Given the current level of scientific knowledge in the area of herbicide pollution, such conclusions are unwarranted. There are at least ninety-four common herbicides, and they all deserve more scientific inquiry.

For example, probably the most well-publicized herbicide is Agent Orange, which was used as a defoliant to improve observa-

321. *Id.* at 12.
322. *Id.*
323. Davis, *Herbicides in Peace and War*, BIOSCIENCE, Feb. 1979, at 84, 91 [hereinafter cited as Davis].
324. Johnston, *supra* note 157 at 67.
325. *See id.*
326. *Id.*
327. *Id.*
328. *See Panic Over Paraquat*, TIME, May 1, 1978, at 24.
329. Johnston, *supra* note 157, at 67.

tion and destroy the food crops of hostile forces during the Vietnam War.[330] Agent Orange consists of a 1:1 mixture[331] of the two phenoxy acids 2,4-D[332] and 2,4,5-T[333] which contain an impurity known as TCDD[334] (commonly referred to as dioxin).[335] TCDD is formed as a by-product of the manufacture of 2,4,5-T, with no sample of that compound being entirely free of TCDD.[336] The concentrations of TCDD found in the Agent Orange used in Vietnam were between 0.1 and 0.5 ppm.[337] In 1980, the 2,4,5-T sold in the United States was much purer and contained less than 0.05 ppm. of TCDD.[338] In October 1969, the Department of Defense restricted the use of Agent Orange in Vietnam to areas which were remote from populated areas.[339] "This action was prompted by a National Institute of Health report that 2,4,5-T could cause malformations and stillbirths in mice."[340] Research later revealed similar problems involving the contaminant TCDD.[341] In April 1970 the Department of Defense suspended all use of Agent Orange in Vietnam. This was approximately the same time period during which

330. *Herbicide "Agent Orange": Hearings Before the Subcomm. on Medical Facilities and Benefits of the House Comm. on Veterans' Affairs*, 95th Cong., 2d Sess. 2 (1978) [hereinafter cited as *1978 Hearings on Agent Orange*]; *see Current Status of Agent Orange Studies: Hearings Before the Subcomm. on Oversight and Investigations of the House Comm. on Veterans' Affairs*, 97th Cong., 1st Sess. 2 (1981) [hereinafter cited as *1981 Hearings on Agent Orange*]; Thomasson, *Deadly Legacy: Dioxin and the Vietnam Veteran*, BULL. AM. SCI., May 1979, at 15.

331. Davis, *supra* note 323, at 92; *see 1981 Hearings on Agent Orange*, *supra* note 330, at 2; *1978 Hearings on Agent Orange, supra note 330, at 2.*

332. The scientific name for 2,4-D is "2,4-Dichlorophenoxy acetic acid." MERCK INDEX 405, Compound 3049 (9th ed. 1976); WEED SCIENCE SOCIETY OF AMERICA, HERBICIDE HANDBOOK 129 (4th ed. 1979) [hereinafter cited as HERBICIDE HANDBOOK 1979].

333. The scientific name for 2,4,5-T is "2,4,5-Trichlorophenoxy acetic acid." MERCK INDEX 1239, Compound 9324 (9th ed. 1976); HERBICIDE HANDBOOK 1979, *supra* note 332, at 418.

334. The scientific name for TCDD is "2,3,7,8-Tetrachlorodibenzo-*para*-dioxin." TCDD is one of the chlorinated dioxins. Rappe, *Chemical Background on the Phenoxy Acids and Dioxins*, 27 CHLORINATED PHENOXY ACIDS AND THEIR DIOXINS, ECOLOGY BULL., 28 (C. Ramel ed. 1978).

335. *Id.*

336. *See Scientific Community Report on Agent Orange: Hearing Before the Subcomm. on Medical Facilities and Benefits of the House Comm. on Veterans' Affairs*, 96th Cong., 2d Sess. 3 (1980) [hereinafter cited as *Report on Agent Orange*]; Galston, *Herbicides: A Mixed Blessing*, BIOSCIENCE, Feb. 1979, at 85, 86 [hereinafter cited as Galston].

337. Galston, *supra* note 336, at 86; *see* Thomasson, *supra* note 330, at 15; Firestone, *The 2,3,7,8-Tetrachlorodibenzo-para-Dioxin Problem: A Review*, in 27 CHLORINATED PHENOXY ACIDS AND THEIR DIOXINS, ECOLOGY BULL. 39, 47 (C. Ramel ed. 1978).

338. *Report on Agent Orange*, *supra* note 336, at 4.

339. *1978 Hearings on Agent Orange*, *supra* note 330, at 3.

340. *Id.*

341. *Id.*

the Deparment of Agriculture restricted the domestic use of 2,4,5-T due to its suspected health hazards.[342] Despite this action, 2.5 million United States military personnel had already been exposed to nearly twenty million gallons of Agent Orange which had been sprayed over an area of Vietnam equivalent in size to the state of Delaware.[343]

A study of births from 1960 to 1969 in Vietnam failed to show any nexus between the herbicides and birth defects; however, this study had several built-in biases.[344] Some reports indicate that exposure to TCDD during industrial accidents has led to "higher incidents or serious health problems and birth defects."[345] In addition, hundreds of the Vietnam veterans who were exposed to Agent Orange during their service "are experiencing serious health problems and birth defects in their offspring."[346] There is growing evidence to support the theory that TCDD accumulates in body fat and causes latent health hazards to humans.[347] It may be another twenty years, however, before the scientific community can determine whether Agent Orange affects cardiovascular disease, malignant disorders and metabolic disorders.[348] In 1978, the EPA determined that the available evidence of human health hazards was substantial enough to support issuance of an emergency order, and in 1979 an order was issued to prohibit the use of 2,4,5-T and Silvex[349] on forest lands.[350] The EPA has since filed an intent to cancel forestry, rights-of-way and pasture registrations of pesticide products containing 2,4,5-T, and certain registrations of pesticide

342. *Id.*

343. *Oversight Hearing to Receive Testimony on Agent Orange: Hearing Before the Subcomm. on Medical Facilities and Benefits of the House Comm. on Veterans' Affairs*, 96th Cong., 2d Sess. 3 (1980) [hereinafter cited as *Oversight Hearing on Agent Orange*].

344. *1978 Hearings on Agent Orange*, *supra* note 330, at 6.

345. *Oversight Hearing on Agent Orange*, *supra* note 343, at 3.

346. *Id.*

347. *See* 44 Fed. Reg. 15,874 (1979); *see also* Davis, *supra* note 323, at 93-94; Galston, *supra* note 336, at 88-89; Henig, *Congress Calls for 2,4,5-T Ban After Dramatic Herbicide Hearings*, BIOSCIENCE, Aug. 1979, 453, 454; Holden, *Agent Orange Furor Continues to Build*, SCI., Aug. 24, 1979, at 770, 770-72; Smith, *EPA Halts Most Use of Herbicide 2,4,5-T*, SCI., Mar. 16, 1979, at 1090-91; Thomasson, *supra* note 330, at 15-19; Tóth, Somfai-Relle, Sugár, & Bence, *Carcinogenicity Testing of Herbicide 2,4,5-Trichlorophenoxyethanol Containing Dioxin and of Pure Dioxin in Swiss Mice*, NATURE, Apr. 5, 1979, at 548.

348. *1981 Hearings on Agent Orange*, *supra* 330, at 6.

349. The scientific name for Silvex is "2-(2,4,5-trichlorophenoxy) propionic acid" or "2-(2,4,5-trichlorophenoxy) propanoic acid." HERBICIDE HANDBOOK 1979, *supra* note 332, at 402.

350. 44 Fed Reg. 15,874 (1979); *see 1981 Hearings on Agent Orange*, *supra* note 330, at 6.

products containing Silvex.[351] In addition, the evidence was substantial enough for the House Committee on Veterans' Affairs to consider an amendment which would provide a presumption of service connection for the occurrence of certain diseases related to the exposure to herbicides during the Vietnam War.[352]

Since most herbicides are either sprayed on farmlands or incorporated into the soil, they would be considered to be a type of land-based pollution. Conceivably, herbicide particles could also be carried by air currents and would therefore constitute a type of air-borne pollution which eventually precipitates into the oceans. Considering the well-documented flow of DDT into the oceans,[353] it is possible to extrapolate and predict that substantial amounts of herbicides have found and will continue to find their way into the oceans, the ultimate sink of mankind's refuse. The Toxic Substances Control Act of 1976 (TOSCA),[354] which was enacted by the United States to control this category of land-based pollution, serves as a good example of the type of national laws and regulations necessary to control land-based pollution under Article 207 of the LOS Convention.[355]

2. *Organochlorine Pesticides: The Chlorinated Hydrocarbons.*

Pesticides generally enter the atmosphere via spraying operations, and to a lesser extent via evaporation.[356] Due to the drifting of the pesticide spray during spraying operations, pesticide particles may be carried many miles by winds before they settle out of the atmosphere.[357] "As a result of transportation through the air and the eventual settling out, almost all land, whether previously treated or not, contains traces of pesticides."[358] Scientists have documented that the transport of pesticides is worldwide, because pesticides are found in Antarctic snow and animal life. However, scientists do not know whether the pesticides are transported to these areas by ocean currents or air currents.[359]

351. 45 Fed. Reg. 15,646 (1980).

352. *H.R. 1961—Vietnam Veterans Agent Orange Relief Act: Hearings Before the Subcomm. on Compensation, Pension, and Insurance of the House Comm. on Veterans' Affairs*, 98th Cong., 1st Sess. 161 (1983).

353. *See* Johnston, *supra* note 157, at 67-69.

354. 15 U.S.C. § 2601 *et seq.* (1976 & Supp. V 1981).

355. LOS Convention, *supra* note 14, art. 207.

356. *Pesticides Problem*, *supra* note 306, at 83.

357. *Id.*

358. *Id.*

359. *Id.*

Pesticides enter the waters from numerous and varied sources. "While the major source of pesticides in water is probably industrial waste, agricultural run-off is also a principal source."[360] Other sources of pesticide pollution of water include "drift from aerial spraying and direct application of pesticides to water as a method of controlling mosquitos."[361]

The compounds comprising DDT and related pesticides are synthesized from petrochemicals and chlorine.[362] With regard to marine pollution, the basic pesticides are:

(1) pp'DDT,
(2) op'DDT,
(3) pp'DDD,
(4) pp'DDE,
(5) aldrin,
(6) dieldrin,
(7) heptachlor, and
(8) endrin.[363]

The first three of these compounds are usually found in any DDT compound and are extremely unsoluble in seawater.[364] However, it is pp'DDE, a derivative of pp'DDT, which is one of the two major types of chlorinated hydrocarbons which affect the marine environment.[365]

The other major chlorinated hydrocarbon impacting on the marine environment is not used as a pesticide but as a component of manufactured products. This chlorinated hydrocarbon consists of the polychlorinated biphenyls (PCBs).[366] PCBs are extensively used by industry, and part of their industrial usefulness "derives from their chemical stability which also ensures that they will persist long after the manufactured products disintegrate.[367] Accordingly, PCBs have a particularly deterimental effect on the marine

360. *Id.*

361. *Id.* at 84; *see* C. EDWARDS, PERSISTENT PESTICIDES IN THE ENVIRONMENT 32-35 (2d ed. 1973).

362. Johnston, *supra* note 157, at 69.

363. For an analysis of the major DDT compounds and other pesticides relating to marine pollution, see Johnston, *supra* note 157, at 68-69; *see also* MERCK INDEX (9th ed. 1976) (the authoritative listing of the chlorinated hydrocarbons and other compounds).

364. Johnston, *supra* note 157, at 69.

365. MARINE ENVIRONMENT, *supra* note 28, at 5; *see* Harvey, *supra* note 283, at 18.

366. MARINE ENVIRONMENT, *supra* note 28, at 5.

367. *Id.*

environment.[368] While definitive evidence is still lacking, preliminary studies indicate that accumulations of PCBs are detrimental to marine life and to humans.[369] PCBs were used for 30 years before their dangerous characteristics were suspected.[370] In August of 1975, PCB contamination of the Hudson River by General Electric was discovered.[371] On February 2, 1976, the Hudson River was closed to most commercial fishing due to PCBs.[372]

Approximately ten million tons of DDT and one million tons of PCBs were produced by the mid-1970's.[373] Some predictions suggest that these compounds tend to "remain in soils rather than be leached into drainage waters."[374] However, there is evidence that significant amounts of these compounds are finding their way into the oceans.[375] Accordingly, marine pollution via DDT and PCBs appears to be basically land-based pollution.

Even so, "[a]ir transport is a major mechanism for dispersing chlorinated hydrocarbons which have been detected in airborn particulate matter, rainwater, and Antarctic snow."[376] Since this "[a]tmoshperic transport and subsequent fallout into the sea can explain the observed distribution and concentrations of both DDT and PCB compounds in the marine environment,"[377] these pollutants should also be categorized as air-borne pollution.

Since aldrin, dieldrin, heptachlor epoxide and endrin are also persistent chlorinated hydrocarbons which are used like DDT, they should be similarly categorized.[378] Dieldrin and heptachlor epoxide "have been detected in resident wildlife in Antarctica,"[379] and dieldrin has also been detected in sea birds.[380] Endrin is extremely poisonous and requires "concentrations of only 2.6 ppb (parts per billion) in water to kill juvenile fish of some species."[381]

368. Johnston, *supra* note 157, at 73-78.
369. *Id.* at 74-78.
370. CONG. RESEARCH SERVICE, WATER POLLUTION: TOXIC CONTAMINANTS 7 (Issue Brief No. IB77071, 1980) [hereinafter cited as Toxic Contaminants Brief].
371. *Id.* at 23.
372. *Id.* at 22.
373. Harvey, *supra* note 283, at 19.
374. MARINE ENVIRONMENT, *supra* note 28, at 6.
375. Harvey, *supra* note 283, at 19.
376. MARINE ENVIRONMENT, *supra* note 28, at 6.
377. *Id.*
378. Johnston, *supra* note 157, at 71.
379. MARINE ENVIRONMENT, *supra* note 28, at 7.
380. *Id.*
381. *Id.*

The sole manufacturer of the pesticides chlordane[382] and heptachlor began the withdrawal of these products from the market in 1978, after the EPA filed notice of its intent to cancel all registered use of these pesticides.[383] After settlement negotiations the manufacturer also agreed to phase out production.[384] For years, chlordane was a leading insecticide in the United States, and in 1972 it was the top insecticide in both home and garden and industrial and commercial usage.[385] However, chlordane and heptachlor were detected in over ninety percent of Americans, and the evidence indicated that their presence posed a human cancer risk.[386] These compounds were found to be carcinogenic in laboratory animals, and because of the similarity of carcinogenic action of chemicals in animals and in humans, a committee of the National Academy of Sciences concluded that chlordane and heptachlor may be carcinogenic in humans as well.[387] In a settlement agreement dated March 6, 1978, the parties agreed to allow the continued use of chlordane and heptachlor on an indefinite basis for termites and on a phase out basis of up to six years for a number of other insects and crops.[388] As a part of this settlement agreement, all parties, including the EPA and the Environmental Defense Fund, "agreed that no findings were to be made as a result of the hearings."[389] Thus, as of 1981 the issue of exposure risks had not been settled.

Kepone (chlordecone) is probably the most dangerous of all the poisons in this area, and is a proven carcinogen.[390] A chlorinated hydrocarbon,[391] kepone is soluble in water and hydrocarbon solvents.[392] In July 1975, the major kepone-producing plant at

382. The empirical formula for chlordane is [Csub10 Hsub6 Clsub8]. Its percentage compostion is C 29.31%, H 1.48%, and Cl 69.22%. MERCK INDEX 2053, Compound 2051 (9th ed. 1976).

383. 40 Fed. Reg. 28,850 (1975).

384. 43 Fed. Reg. 12,372 (1978).

385. 41 Fed. Reg. 7552, 7558 (1976).

386. *Id.* at 7552-53.

387. VELSICOL CHEMICAL CORPORATION, CHLORDANE FORMULATION GUIDE 8 (Feb. 1, 1981).

388. *Id.* at 20.

389. *Id.*

390. *See* MERCK INDEX 263, Compound 2053 (9th ed. 1976) [hereinafter cited as Compound 2053].

391. *See Kepone Contamination in Hopewell, Virginia: Hearings Before the Subcomm. on Agricultural Research and General Legislation of the Comm. on Agriculture and Forestry*, 94th Cong., 2d Sess. 4 (1976) (Statement of Gov. Mills E. Godwin, Jr.) [hereinafter cited as *Kepone Hearings*].

392. Compound 2053, *supra* note 390.

Hopewell, Virginia was closed after workers in the plant began developing tremors and experiencing birth defects in their children.[393] Even so, the aquatic life in the James River and the Chesapeake Bay was irretrievably contaminated. On December 18, 1975, the James River was closed to commercial fishing due to the kepone.[394]

The kepone from the Hopewell plant was so toxic that no state or country would accept it for disposal. Proposals to dump or burn the kepone at sea were rejected due to the international uproar which resulted in response to the suggestion. The kepone was finally accepted by West Germany for disposal in an underground salt dome. It was not until 1980 that much of the James River was reopened. This situation constitutes a prime example of what damage can be done when poisons are produced and marketed before their environmental effects have been adequately tested.

In the United States, kepone was used in minute amounts as the active ingredient in ant and roach traps. Kepone was also exported to South America, where it was used in a different form as an insecticide spray for bananas.[395] Little is known about the chemical kepone and its affects upon people.[396] The concentration of kepone which is acceptable in the environment is unknown, and similarly the level of kepone concentration in the human body which produces symptoms of illness is as yet undetermined.[397] However, heavy exposure such as that experienced by the employees at the kepone plant in Hopewell, Virginia has produced symptoms of neurological damage and other disorders.[398] Like other chlorinated hydrocarbons, kepone tends to concentrate in the liver and the fatty tissues of the body.[399] There was some speculation that the human body and aquatic life might be able to dispel the kepone chemicals, but the results of research with related chemicals were not encouraging.[400]

Pesticides may pose an imminent threat to human life. This finding compelled the EPA, in September 1983, to issue an emergency order suspending registrations of pesticide products contain-

393. Toxic Contaminants Brief, *supra* note 370, at 23.
394. *Id.* at 22.
395. *Kepone Hearings*, *supra* note 391, at 4.
396. *Id.*
397. *Id.* at 4-5.
398. *Id.* at 5.
399. *Id.*
400. *Id.*

ing ethylene dibromide (EDB).[401] EDB was registered as a fumigant; ninety percent of its domestic use being as a preplant application to soil.[402] The EPA determined that EDB constitutes: (1) a potent animal carcinogen, (2) a mutagen to a variety of plant and animal cells, (3) a potential cause of adverse reproductive effects in animals, and (4) a potential cause of adverse health effects in humans at measurable levels in the human diet and in the ambient air of EDB application sites.[403] Evidence indicated that use of EDB is likely to result in leaching to groundwater and in contamination of human drinking water sources. Some groundwater contamination has already been discovered.[404] The EPA ordered the emergency suspension of EDB after concluding that the total economic benefits of continued use of EDB as a soil fumigant during the six-month to two-year period that hearings would delay suspension or cancellation did not outweigh the human health risks expected from increased contribution to groundwater contamination by the soil fumigant uses of EDB, and from occupational exposure to EDB during this time period.[405]

3. *Insecticides.*

The insecticides polluting the marine environment generally consist of the organo-phosphorus insecticides—primarily azodrin, coral, dipterex, guthion, malathion and parathion.[406] Like DDT, these insecticides are nerve poisons,[407] and "virtually nothing is known about organo-phosphorus insecticides in marine organisms and the extent of knowledge of their effects elsewhere is hard to assess."[408] However, most of these insecticides "are very toxic to freshwater fishes though not as toxic as DDT and they are not retained like DDT if acquired in sublethal doses but are slowly inac-

401. EPA, NOTICE OF DECISION AND EMERGENCY ORDER SUSPENDING REGISTRATIONS OF PESTICEDE PRODUCTS CONTAINING ETHYLENE DIBROMIDE FOR USE AS A SOIL FUMIGANT, OPP-68012 (1983) [hereinafter cited as ORDER SUSPENDING EDB]; *see also* EPA, NOTICE OF INTENT TO CANCEL REGISTRATIONS OF PESTICIDE PRODUCTS CONTAINING ETHYLENE DIBROMIDE; NOTICE OF DETERMINATION CONCLUDING THE REBUTTABLE PRESUMPTION AGAINST REGISTRATION; NOTICE OF AVAILABILITY OF POSITION DOCUMENT, OPP-30000/25D (1983).

402. OFFICE OF PESTICIDE PROGRAMS, ENVTL. PROTECTION AGENCY, ETHYLENE-DIBROMIDE EDB POSITION DOCUMENT 4i (1983).

403. *Id.* at 102.

404. ORDER SUSPENDING EDB, *supra* note 401, at 12.

405. *Id.* at 26.

406. Johnston, *supra* note 157, at 72.

407. *Id.*

408. *Id.*

tivated and excreted."[409] While these insecticides apparently do not bioaccumulate like DDT, their toxicity and potential danger should not be underestimated or discounted.

In addition, carbamate insecticides are also used, but research concerning the safety of methylcarbamate insecticides is sketchy. In particular, aldicarb (trade name, Temik)[410] serves as an example of a chemical compound which needs to be thoroughly tested to insure its safe use. Aldicarb is designed to be used as a soil application to control certain insects, mites and nematodes on cotton, sugar beets, potatoes, peanuts, oranges, pecans, soybeans and other crops.[411] Testing has revealed that aldicarb is one of the most toxic of the carbamate insecticides.[412] Aldicarb and other insecticides represent increased carcinogenic risks when they combine with nitrite to form nitrosomethylcarbamates.[413] Nitrites are commonly found in the environment or in the stomach. Tests on laboratory animals revealed high incidences of death and stomach tumors when nitrosoaldicarb and other N-nitroso derivatives were administered to the test animals.[414] Further studies indicate that these N-nitroso derivatives irreversibly damage human DNA cells.[415]

Although clinical experience involving poisoning of humans by insecticidal carbamates has not been extensive, there have been some reported cases.[416] Two suspected occurrences, in 1977 and 1978, involved groups of people who became violently ill following ingestion of locally grown hydroponic cucumbers.[417] Hyproponics is the science which deals with growing plants in a nutrient solution.[418] Aldicarb was detected in both the uneaten cucumbers

409. *Id.*

410. The chemical name for aldicarb is z-methyl-z-(methylthio)-propionaldehyde O-(methylcarbamoyl)oxime. MERCK INDEX 215, Compound 217 (9th ed. 1976); FARM CHEMICALS HANDBOOK C 281 (1982) [hereinafter cited as CHEMICAL HANDBOOK].

411. CHEMICAL HANDBOOK, *supra* note 410, at C 281.

412. *See* R. GOSSELIN, H. HODGE, R. SMITH & M. GLEASON, CLINICAL TOXICOLOGY OF COMMERCIAL PRODUCTS 80 (1976) [hereinafter cited as GOSSELIN].

413. Lijinsky & Schmähl, *Carcinogenicity of N-Nitroso Derivatives of N-Methylcarbamate Insecticides in Rats*, 2 ECOTOXICOLOGY & ENVTL. SAFETY 413, 418 (1978) [hereinafter cited as Lijinsky]; Blevins, Lijinsky & Regan, *Nitrosated Methylcarbamate Insecticides: Effect on the DNA of Human Cells*, 44 MUTATION RESEARCH 1 (1977) [hereinafter cited as Blevins].

414. Lijinsky, *supra* note 413, at 416.

415. Blevins, *supra* note 413, at 1, 3-4.

416. GOSSELIN, *supra* note 412, at 80.

417. Goes, Savage, Gibbons, Aaronson, Ford & Wheeler, *Suspected Foodborne Carbamate Pesticide Intoxications Associated with Ingestion of Hydroponic Cucumbers*, 111 AM. J. EPIDEMIOLOGY 254, 254 (1980).

418. *Id.* at 255.

grown at the greenhouse and in materials from the greenhouse, and it was suspected that aldicarb was the cause of the illnesses.[419]

In addition to laboratory testing of insecticides, field testing must be conducted to insure the safety of the environment. One study revealed that the insecticide aldicarb "is mobile, especially in wet soil, systemic in plants and can be found widely in the local vertebrate fauna for up to 90 days after application."[420] Specific hazards identified include the ingestion of uncovered granules and worms containing aldicarb residues.[421] Other studies have revealed aldicarb residues in weeds and grasses,[422] sugar beets,[423] and the rind and pulp of oranges.[424] Plants grown in the treated soil absorb the toxicant and translocate it to various parts of the plant. One study, however, indicated that residues of aldicarb do not persist in the soil after a 90-day growing season.[425]

C. Plastics

Since plastics are by-products of the hydrocarbons, it is appropriate to review their effect on the marine environment. Plastics are actually a subcategory of the litter that is found floating in the oceans. Since plastics tend to float, they constitute a noticeable type of litter that generally results from the land-based pollution or ocean dumping of municipal wastes and garbage into the oceans. For example, New York City has been dumping municipal garbage into the oceans for years.

> During the past few years several expeditions have found large amounts of plastic and polystyrene particles floating on the ocean surface. Concentrations as high as 12,000 particles per

419. *Id.* at 259.

420. Bunyan, van den Heuvel, Stanley & Wright, *An Intensive Field Trial and a Multi-Site Surveillance Exercise on the Use of Aldicarb to Investigate Methods for the Assessment of Possible Environmental Hazards Presented by New Pesticides*, 7 AGRO ECOSYSTEMS 239, 239 (1981) [hereinafter cited as Bunyan]; *see also* Woodham, Reeves & Edwards, *Total Toxic Aldicarb Residues in Weeds, Grasses, and Wildlife from the Texas High Plains Following a Soil Treatment with the Insecticide*, 21 J. AGRIC. & FOOD CHEMISTRY 604 (1973) [hereinafter cited as Woodham].

421. *See* Bunyan, *supra* note 420, at 239.

422. *See* Woodham, *supra* note 420, at 604.

423. Beckman, Giang & Qualia, *Preparation and Detection of Derivatives of Temik and Its Metabolites as Residues*, 17 J. AGRIC. & FOOD CHEMISTRY 70, 70 (1969).

424. Iwata, Westlake, Barkley, Carman & Gunther, *Aldicarb Residues in Oranges, Citrus By-Products, Orange Leaves, and Soil after an Aldicarb Soil-Application in an Orange Grove*, 25 J. AGRIC. & FOOD CHEMISTRY 933, 933 (1977).

425. Andrawes, Bagley & Herrett, *Fate and Carryover Properties of Temik Aldicarb Pesticide in Soil*, 19 J. AGRIC. & FOOD CHEMISTRY, 727, 730 (1971).

> square kilometer have been detected in the Sargasso Sea off the east coast of the United States. Such large concentrations probably reflect increased production of plastics on land and subsequent dumping at sea. The plastic particles can serve as an area of attachment for small plants and animals. Many of the plastics contain PCB's, however, which are a dangerous pollutant.[426]

A study in the early 1970's by a program of the United States National Marine Fisheries Service entitled Marine Resource Monitoring, Assessment, and Prediction (MARMAP) reported significant amounts of plastics in the oceans.[427] In addition to the large pieces of plastic refuse, there are: (1) small plastic pieces, (2) plastic sheets, (3) paint chips, (4) opaque polystyrene particles, (5) clear polystyrene spherules, (6) polyethylene cylinders, (7) Styrofoam pieces, and (8) miscellaneous plastics from cigarette filters, and so forth.[428] While these plastics are not toxic per se, it has been suggested that marine life which ingest plastics have intestinal blockage which may result in death.[429] More importantly, the plastics may gradually break into smaller pieces but they never decompose. In fact, they remain in the oceans indefinitely.[430] It is not unreasonable to extrapolate and predict that microscopic plastic particles will tend to bioaccumulate in the food chain.

II. SUMMARY AND CONCLUSION

Part XII of the LOS Convention sets forth a comprehensive regime for protection of the marine environment.[431] Pollution of the oceans by oil has traditionally been considered as vessel-source pollution which is governed by Article 211 of the LOS Convention.[432] However, large amounts of oil wastes that are entering the oceans are classified as land-based pollution under Article 207[433] and as air-borne pollution under Article 212.[434] In addition, oil spills from seabed activities, such as the Pemex oil spill, would be governed by Article 208.[435]

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426. ROSS 1982, *supra* note 78, at 448.

427. *See* Colton, *Plastics in the Ocean*, OCEANUS, Fall 1974, at 61, 61-64.

428. *Id.*

429. *Id.*

430. *Id.*

431. *See generally* Comment, *Offshore Petroleum Exploitation and Environmental Protection: The International and Norwegian Response*, 17 SAN DIEGO L. REV. 629, 641-42 (1980).

432. LOS Convention, *supra* note 14, art. 211.

433. *Id.* art. 207.

434. *Id.* art. 212.

435. *Id.* art. 208.

The majority of LNG pollution will probably enter the marine environment as a result of accidents involving vessels or harbor facilities. Accordingly, the vessel-source or land-based pollution provisions would apply. Since LNG rapidly vaporizes when it comes into contact with air, the air-borne pollution provisions might also apply in certain situations. While it is generally burned away at its discharge point, the deliberate discharge of natural gas into the air as incident to the regular functioning of oil fields would constitute air-borne pollution.

Poisons such as the DDT compounds and industrial wastes such as PCBs, both of which are hydrocarbon by-products, appear to enter the oceans primarily as air-borne pollution, but significant amounts enter the oceans via the world's river systems and are therefore a type of land-based pollution. In an attempt to dispose of unwanted poisons, ocean dumping has been utilized in the past but Article 210 of the LOS Convention will restrict this disposal method in the future.[436]

The plastics, which are also hydrocarbon by-products, generally enter the oceans as wastes via river systems or via deliberate ocean dumping. Therefore, the LOS Convention provisions regulating the introduction of plastics into the marine environment would be those provisions governing land-based pollution and ocean dumping.[437]

The detrimental effects which are being caused by the regular discharge of these pollutants into the marine environment are more serious than might be expected. Even though the scientific studies in this area are relatively new and limited in scope, the preliminary results point to serious threats to marine ecosystems. Since the oceans are large, they are deceptive with regard to the amount of pollution they can absorb. However, if the threshold capacities of vital marine ecosystems are passed, there may be a chain-reaction collapse of parts of the oceans. There may also be detrimental synergistic effects which are unpredictable. The sudden and generally unexpected collapse of the entire ecosystem in Lake Erie serves as a microcosm of what could happen worldwide. There is substantial evidence that the Mediterranean Sea may be approaching a similar ecological collapse. These situations have provided mankind with warnings of what is to be expected if marine pollution continues

436. *Id.* art. 210.

437. *See id.* arts. 207, 210.

unabated. The LOS Convention provisions provide a good basis for beginning to solve these problems.